DEPARTMENT OF DEFENSE WEATHER PROGRAMS

The Department of Defense (DOD) operates a military environmental service system to provide specialized worldwide meteorological, space environmental and oceanographic analysis and prediction services in support of military forces. This system directly supports all phases of military operations, from strategic planning to tactical operations. While the Army and Marine Corps each have a small specialized weather support capability, the Naval Meteorology and Oceanography Command and Air Force Weather are the primary sources of military weather products. The military weather services contribute to the national and international weather observing capability by taking conventional observations on land and at sea where there are no other conventional weather observing capabilities and where the observations are most needed to meet military requirements. In addition, DOD maintains specialized observing capabilities, such as the Defense Meteorological Satellite and Global Weather Intercept Programs, to meet unique military requirements. Observational data are sent by military communications networks to military and civil facilities in the United States and overseas.

UNITED STATES AIR FORCE

METEOROLOGICAL SERVICES

The Air Force functional manager for meteorological and space environmental services is the Director of Weather within the Headquarters, United States Air Force (HQ USAF/XOW), Deputy Chief of Staff for Air and Space Operations. HQ USAF/XOW oversees the development and implementation of weather support concepts, doctrine, policies, plans, and programs to ensure effective weather support for the Air Force, Army, and other agencies as directed by the Chief of Staff, USAF. The Air Force also provides support to DOD Joint operations as directed by the Joint Chiefs of Staff under the Unified Action Armed Forces (JCS Publication O-2) document. HQ USAF/XOW interfaces with other military departments, federal agencies, and international organizations concerning coordination, cooperation, standardization, and interoperability of weather services.

Air Force Weather (AFW) Organization. AFW is a Total Force organization, employing the active forces as well as Air Force Reserve and Air National Guard weather personnel. The active component of AFW has nearly completed reengineering to mirror the three levels of military operations--strategic, theater (operational), and tactical. The Air Force Weather Agency (AFWA), a field operating agency (FOA) reporting to HQ USAF/XOW, provides strategic-level weather support (global and synoptic-scale) for their worldwide customers, as well as fulfilling some unique mission requirements (discussed later). HQ AFWA, located at Offutt AFB, Nebraska, has two subordinate centers: the Air Force Combat Climatology Center (AFCCC) at Asheville, North Carolina, and the Air Force Combat Weather Center (AFCWC) at Hurlburt AFB, Florida. Space environmental support is split between HQ AFWA and the 55th Space Weather Squadron (55 SWXS) at Schriever AFB, Colorado, as the transition of strategic-level space weather functions to AFWA continues. Eight Operational Weather Squadrons (OWSs) serve in direct support of overseas theater CINC and/or Numbered Air Force (NAF) operations. Each OWS is designated as the forecast agency for a specific geographical Area of Responsibility (AOR) in concert with their supported NAFs or Theater's AOR (Figure 3-DOD-1). Continental United States (CONUS) OWSs are also responsible for CONUS regional weather support. They produce and disseminate terminal forecasts, weather warnings and advisories, planning and execution area forecasts, and other operational products to Combat Weather Teams (CWTs). The CWTs, located at the base and post level, take and disseminate local observations and provide mission-tailored forecasts and briefings based on centrally produced guidance. In addition to the active duty force, approximately 110 weather officers serve as Air Force Reserve individual mobilization augmentees assigned to various active AFW units at all levels. They typically train during two days each month and for two weeks each year. The Air National Guard (ANG) program consists of two distinct functions. The traditional program consists of 33 weather flights, ranging in size from 13 to 25 personnel. The flights meet monthly to train for their wartime missions and support both Army National Guard (ARNG) and United States Army Reserve (USAR) units as well as ANG flying units. The ANG operates the Weather Readiness Training Center at Camp Blanding in Starke, Florida, to provide Army tactical skills training that is not available elsewhere in the Air Force. The ANG is also responsible for peacetime weather operations at locations where the ANG is responsible for airfield support. Total Force AFW per-

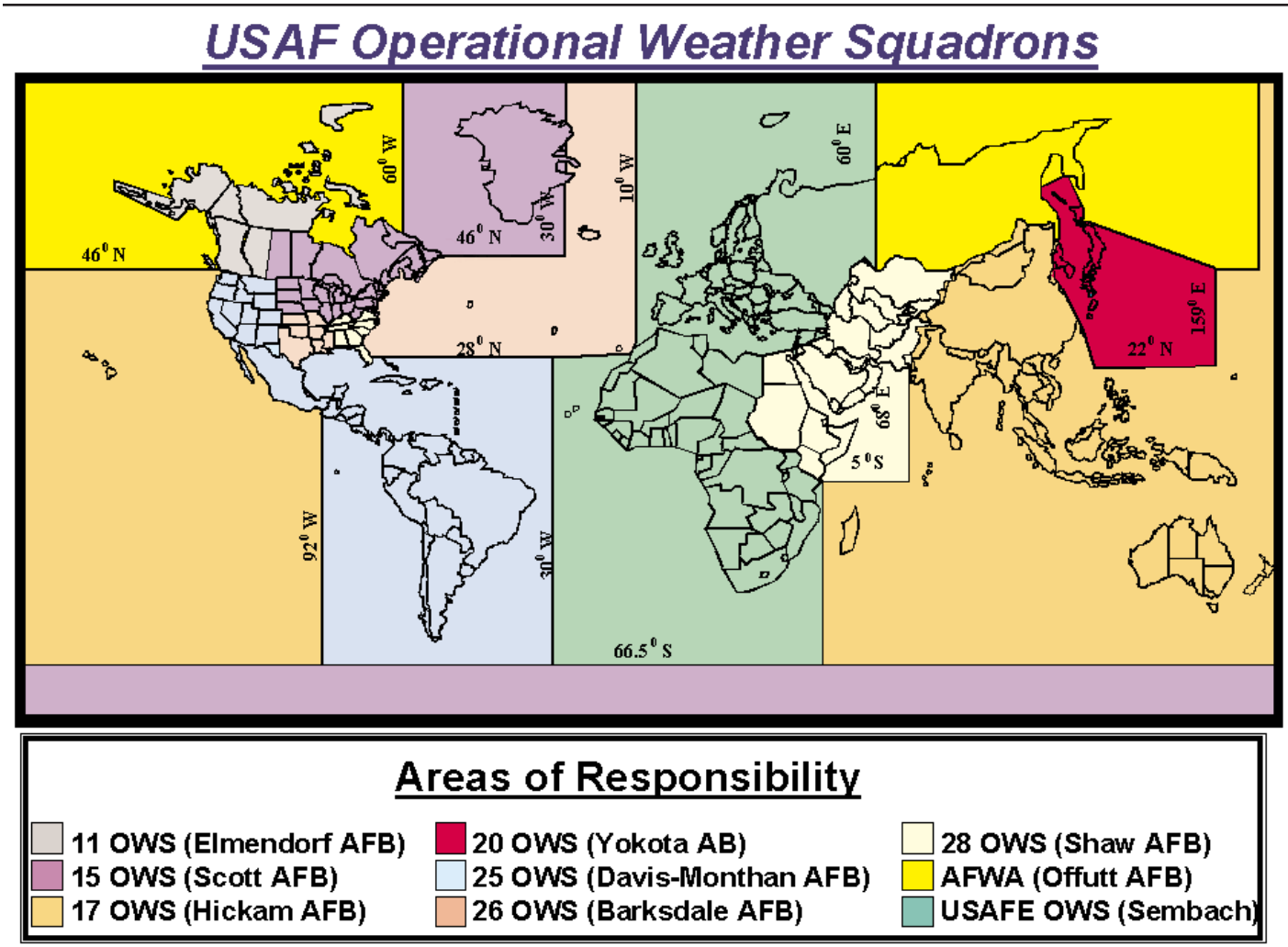


Figure 3-DOD-1. Areas of Responsibility for Air Force Weather's Operational Weather Squadrons.

sonnel enhance the unique global capability of ground and aerospace military operations, while indirectly assisting civil aviation by providing flight weather briefings, air/ground radio services, and tailored observations, forecasts, watches, and warnings for military operations.

To fulfill its global mission of providing timely, accurate, and relevant weather information, AFW maintains and continually improves on its five core processes: data collection, analysis, forecasting, tailoring, and dissemination. The following paragraphs provide more information on each of these areas.

Weather Data Collection integrates the spectrum of remote and *in situ* sensors into a single meteorological sensing and instrumentation approach for battlefield and in-garrison operations. Data collection in the space environment is discussed in the Space Environmental Services section.

AFW personnel take surface observations to support military operations and for weather analysis and forecasting. Weather personnel at both Air Force and Army locations (fixed and tactical) make observations available to local users and transmit them to military and civil locations throughout the world via the Automated Weather Network (AWN). Upper air observations provide vital input to numerical weather analysis and prediction. United States and foreign rawinsonde reports are primary sources and are supplemented with military and civilian pilot reports. The Observing System 21st Century (OS-21) program provides a much-needed, state-of-the-art, life-cycle replacement for Air Force observing equipment. OS-21 includes five different configurations: fixed, deployable, remote, manual, and upper air. The manual configuration is intended for tactical operations and continues the improvements begun under the Manual Observing System (MOS) and Tactical Meteorological Observing System Modification (TACMET MOD) programs. For remote observations, AFW purchased commercial off-the-shelf Remote Miniature Weather Sensors to provide accurate real-time weather information from forward unmanned locations. Installation of the new fixed configuration should begin in FY 2002.

Weather radar is a principal source of information needed to produce severe weather warnings. Within the CONUS, AFW uses the WSR-88D. DOD, NOAA, and the FAA operate

and maintain the radars within CONUS and the Air Force operates and maintains the overseas radars. Tactical Weather Radars (TWRs) are used to support worldwide military contingency operations by providing tactical/deployable weather radar capability, replacing existing radars at deployed locations and at select fixed locations overseas.

The Defense Meteorological Satellite Program (DMSP), which provides a large volume of cloud, upper air, and space environmental data, is a vital source of global weather data used for combat support. On-board sensors provide AFWA, 55 SWXS, and the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) with visible, infrared, and microwave imagery of the entire globe, temperature and moisture sounding data, electrically charged particle fluxes, and other specialized space environment data. DMSP also supplies direct, real-time readout of regional imagery and mission-sensor data to DOD land-based and shipborne terminals located worldwide.

The present DMSP satellite series (Block 5D-2) uses the Operational Linescan System to provide visible imagery to optimize distinction among clouds, ground, snow, and water. The DMSP also flies a microwave temperature and moisture sounder (SSM/T, SSM/T-2) which provides vertical temperature, moisture, and height profiles of the atmosphere, providing key data for numerical analysis and forecasting. The microwave imager (SSM/I) observes rainfall, ocean surface wind speed, cloud and soil moisture, ice conditions, and other environmental data. The Block 5D-3 spacecraft will begin service in November 2001 with the launch of DMSP Flight 16. The new spacecraft will provide enhanced microwave imaging and sounding through the SSMIS system as well as several other improvements.

AFW continues to participate in the refinement of requirements for the National Polar-orbiting Operational Environmental Satellite System (NPOESS). NPOESS will replace the existing DMSP and NOAA polar-orbiting satellite systems beginning in approximately 2010 and is a joint Department of Defense, Department of Commerce, and NASA program. The new system will also provide a direct readout capability for tactical users similar to DMSP. AFW also expects to gain operational experience as well as benefit from the risk reduction planned with the NPOESS Preparatory Program (NPP) planned for launch in CY 2005.

To receive environmental current satellite downlinks, the Small Tactical Terminal (STT) provides worldwide tactical users with a survivable "first-in" source of meteorological satellite data, processed by small, portable terminals in forward areas of conflict. These terminals process remotely-sensed visual and thermal imagery and other non-imagery weather data from both polar-orbiting and geostationary satellites to support combat forces.

The Air Force Reserve Command's 53rd Weather Reconnaissance Squadron (53 WRS) "Hurricane Hunters" provide another means of collecting vital meteorological data, especially in and around tropical cyclones. Their specially-equipped WC-130 aircraft collect temperature, moisture, wind, pressure, and visually-observed information at the aircraft location as well as vertical profiles of the atmosphere collected by dropwinsondes. They penetrate the eyes of tropical cyclones to provide a very accurate center fix location as well as providing meteorological parameters, including sea level pressure, to the National Hurricane Center. In addition to the tropical cyclone reconnaissance mission, the 53 WRS collects meteorological information to improve wintertime West Coast forecasts as well as supporting scientific field programs when possible. For more information, see their web site at *http://www.hurricanehunters.com/*.

Analysis and Forecasting. AFWA is the primary strategic production center for weather analyses and forecasts while the OWSs are the primary theater-scale production centers for Air Force and Army operations. AFWA uses a networked computer system and an interactive graphics and imagery system to implement a "build-and-apply" concept. World-wide weather data are relayed to AFWA and blended with civil and military meteorological satellite data to construct a real-time, integrated environmental database. Computer programs further digest the data to construct models of the atmosphere and to forecast its future behavior. Manual tailoring of the data is critical for application to the specific needs of the warfighters. The interaction between forecaster and machine is accomplished with the Satellite Data Handling System (SDHS). SDHS consists of interactive workstations capable of high-speed manipulation of satellite and conventional meteorological data to prepare forecasts and other environmental products. AFWA also

provides backup for the National Weather Service's (NWS) Storm Prediction Center and Aviation Weather Center.

AFWA has organized forecast operations to achieve greater flexibility and focus production on its primary customers. Forecasts are generated in the agency's Global Weather Center Division, which consists of four production branches: Forecast Production, Special Support Operations, National Programs Operations, and Satellite Applications.

The Strategic Section of the Forecast Production Branch produces tailored worldwide meteorological analyses and forecasts in support of aviation customers. The branch also provides forecasts of CONUS low-level aviation hazards. The CONUS Severe Forecast Section provides specific point weather warnings for Air Force and Army installations in the CONUS and hot backup to Aviation Weather Center and Storm Prediction Center. The American Forces Network Section provides worldwide, broadcast-quality public weather services and planning forecast support through the American Forces Television Network to DOD personnel and family members stationed overseas.

The Special Support Operations Branch (SSOB) provides worldwide mission-tailored forecasts to Joint Special Operations Forces (SOF). The branch acts as a clearinghouse for unique data requests from the SOF customers; provides end-to-end targeting support to unified command, component, and national customers; produces long-range (4-8 day) forecasts to unified command, component, and national customers; and supplies the Nation's reconnaissance cloud-free forecast products. SSOB is also in the process of accepting portions of the space-forecast mission from the 55 SWXS. As the space weather mission transitions from 55 SWXS to HQ AFWA, SSOB provides worldwide general and tailored analyses, forecasts, advisories, and warnings for space weather phenomena that can affect military operations and National Programs activities. The branch provides products for agencies from all DOD Services using space weather measurements from a variety of ground- and space-based sensors. Data sharing and forecast coordination is performed with the NOAA Space Environment Center (SEC) in Boulder, Colorado.

The National Programs Operations Branch provides weather support for classified National Programs directed by the Secretary of the Air Force. The branch produces detailed global cloud analyses to update and refine the Real Time Nephanalysis (RTNEPH) database. The branch identifies and documents weather service requirements and initiates actions to ensure Sensitive Compartmented Information (SCI) and Special Access Program (SAP) weather support needs are met. They serve as the focal point for AFWA SAPs; ensure National Program and other SCI and SAP support requirements are integrated into AFWA programs; monitor and evaluate accuracy and timeliness of centralized weather services to National Programs; and interface with the DOD and national intelligence community regarding weather services and exploitation of weather information.

The Satellite Applications Branch provides rapid response tailored METSAT imagery and evaluation for DOD contingency mission support. The branch produces regional snow and ice cover analyses to update and refine the Snow Depth (SNODEP) database; and generates automated METSAT imagery products for unclassified and classified web-based distribution to DOD customers. The branch also tracks and classifies tropical cyclones (METSAT analysis) for the DOD Joint Typhoon Warning Center (JTWC) and other United States tropical cyclone warning centers; provides hot back up for JTWC satellite operations; backs up the Washington Volcanic Ash Advisory Center; monitors operational status; and evaluates quality of imagery ingested at AFWA. They coordinate corrective actions; maintain, modify, and develop new capabilities to display and visualize satellite imagery on workstations; infuse state-of-the-art techniques into improved imagery analysis ensuring high quality customer products; serve as AFW focal point on technical issues regarding METSAT imagery utilization; and interface with the DMSP System Program Office, Air Force Space Command, and other DOD and governmental agencies on METSAT data exploitation issues.

On-going modernization initiatives at AFWA include the Cloud Depiction and Forecasting System (CDFS) II, Global Theater Weather Analysis and Prediction System (GTWAPS), Space Weather Analysis and Forecasting System (SWAFS), and modernization of the communications and data processing infrastructure including a significant increase in the database capacity. CDFS II brings major software and hardware modifications at AFWA to upgrade the weather satellite data processing, cloud depiction and forecasting, and classified weather support functions for operational customers and National Programs, providing a capability that cannot be met with the current system. The GTWAPS program is nearly complete and will improved interaction of the strategic and OWS theater-level forecasting systems. The key software component of the GTWAPS program is a theater analysis and forecast model--Mesoscale Model version 5 (MM5), which provides highly accurate, fine-scale forecast data. SWAFS will integrate additional space weather data sources and execute next-generation space weather models in support of DOD and National Programs operations.

Figure 3-DOD-2. AFW personnel from Wright-Patterson Air Force Base, Ohio, scan up-to-the-minute weather charts and satellite reports to provide United States and Australian command and control operators critical flight safety information for Global Hawk.

OWSs provide theater-scale battlespace forecasts; drop zone, range, and aerial refueling track forecasts; fine-scale target forecasts; and airfield forecasts and warnings for Air Force and Army installations within their area of responsibility. Their primary tool is the OWS Production System II (OPS-II), used to ingest data and strategic center information, create and disseminate theater-scale products.

Product Tailoring/Warfighter Applications. Progressive focusing and tailoring of weather information is the heart of the reengineered AFW organization, leading to individual mission-specific support at the CWT level. An example of specific mission tailoring performed for an emerging system still in testing is the Global Hawk high-altitude reconnaissance system and the turbulence forecasts provided by the weather support team (Figure 3-DOD-2). The Forecasting System 21st Century (FS-21) program is the vehicle for providing necessary computer hardware and software at both the OWSs and CWTs. The OWS Production System, Phase 2 (OPS-II), is the backbone of the OWS production system. This hybrid system of databases, servers, and workstations, provides the computer hardware and software necessary for OWSs to produce and disseminate forecast products to CWTs.

The New Tactical Forecast System (N-TFS) provides in-garrison and deployed CWT personnel the meteorological tools necessary to manipulate and disseminate graphical and alphanumeric products (satellite imagery, graphical forecast products, weather forecasts, advisories, briefings, observations, etc.) to Army and Air Force operational, command and control, and support forces worldwide. N-TFS provides weather personnel the ability to use the same system in "peace and war", thus providing a robust "first in" and sustainment weather forecast capability to combat weather units worldwide. Additionally, N-TFS ingests data from Air Force observing systems and observations from indigenous sources. Data from the N-TFS, combined with satellite imagery from the STT, provide the essential capability required for deployed weather units to meet operational mission requirements.

Dissemination. The AFW dissemination system uses a variety of media to meet the needs of its worldwide customer base. High-speed communications between large DOD and civilian processing centers facilitate sharing of data, high-resolution satellite imagery, and output from numerical weather prediction models. Additional circuits provide a subset of this data to the OWS facilities. Forecaster-developed products and gridded data sets are distributed from HQ AFWA via the Communications Front-End Processor to base and post weather stations worldwide using dedicated 9600-baud circuits. AFW will continue replacing these dedicated circuits in FY 2002 with commercial Kμ-band broadcast satellites over the CONUS, Europe, and the Pacific, saving significant communications costs by eliminating the network of expensive landlines to each weather station.

Alphanumeric data including synoptic, upper-air, and pilot reports are collected and distributed via the AWN. The AWN is a collection of dedicated circuits ranging from 74-baud to 56kbps linking DOD, national and international facilities worldwide. Data is also received from DOD-operated High Frequency (HF) radio receiver sites strategically positioned around the globe to intercept weather broadcasts. These broadcasts originate from nations that do not routinely make data available through World Meteorological Organization (WMO) channels. The Automatic Digital Weather Switch at Tinker AFB, Oklahoma, receives alphanumeric weather data and Notices to Airman (NOTAMs), parses them according to data type, eliminates duplicate reports from different sources, and creates specially tailored bulletins. Some of these bulletins are sent to the large processing centers to provide the input data for global, regional, and fine-scale forecast models. Other bulletins are redistributed to end users over: (1) the same dedicated circuits, (2) the DOD's Non-secure Internet Protocol Router Network (NIPRNET), and (3) HF and satellite broadcast facilities. The current HF Regional Broadcast (HFRB) system will be terminated in FY 2002 and replaced by more reliable satellite-based, worldwide-capable communications.

AFW utilizes the NIPRNET to host the Joint Air Force-Army Weather Information Network (JAAWIN) and the Military Aircrew Information System (MAIS). JAAWIN provides worldwide access to numerical model forecast graphics, satellite imagery, and text bulletins. MAIS uses aircrew mission parameters and provides weather data for the takeoff base, route of flight, and destination. MAIS will be replaced in FY 2002.

Additional means of dissemination of tailored weather information include the Joint Weather Impacts System (JWIS). JWIS provides a link to weather information from both AF and Navy sources for use by command and control users and applications. AFW successfully demonstrated JWIS during Joint Expeditionary Force Experiment 2000 and is integrating the initial capability into the Combined Air Operations Center-Experimental (CAOC-X) in 2001. AFW is also seeking rapid acquisition process funding in FY 2002 for the Weather Impacts Information Integration (WI^3) initiative to provide a four-dimensional weather data cube to feed decision aids integrated in command and control systems.

Finally, AFWA established in 2001 an initial capability to provide weather information to any AF user through the new Air Force Portal, a system designed to be a "one-stop shop" for all support-type activities for all AF personnel. Additional capabilities will be added in 2002.

Unique Support Requirements. A special aspect of the military weather mission is the need to provide decision assistance to commanders and resource managers as well as operational units. To fulfill this requirement, designated AFW personnel serve as part of the staff of operational Air Force, Army, and joint force units. In this capacity, AFW personnel identify all weather-sensitive areas of the operation, monitor the weather service provided in these areas, and provide expert advice to mitigate weather impacts on training or combat operations. Support is tailored to the needs of weapon systems being developed or used, command and control systems, Army firing units, research, development and evaluation, testing, training and deployment of military forces, and contingency operations. This effort helps ensure that Air Force, Army, and joint force units fulfill their missions regardless of the weather and results in efficient use of weather resources by gearing them to mission specific requirements.

The Army weather support mission is completely integrated into the Air Force's overall mission concept. The Army trains and educates Air Force personnel about Army organizations, concepts of operations, and the weather sensitivities of Army operations and equipment. AFW units are aligned and integrated with the Army intelligence organization. Weather products are tailored to be directly usable and understandable by Army personnel and are integrated into Army communications systems. Mobile and fixed meteorological equipment is programmed by the Air Force. In a tactical environment, weather personnel serve with echelon-above-corps, corps, divisions, separate brigades, regiments, aviation brigades, armored cavalry regiments, ranger regiments, and special forces groups (as well as subordinate battalions deployed at forward operating bases). The Air Force provides observer support to all command levels identified above. The Army Forward Area Limited Observing Program (FALOP) and the Army artillery meteorology (ARTYMET) program augment the Air Force observations in the tactical environment.

The Air Force provides meteorological products to the Nation's space and missile programs. This support includes a wide range of weather observing services at the Air Force Eastern Range and the Kennedy Space Center. The Air Force provides tailored forecasting for NASA's manned and unmanned launches and for commercial launches from the Kennedy Space Center. The Air Force also provides specialized meteorological services for the Air Force Western Range at Vandenberg AFB, California, and the Pacific Missile Range which includes Point Mugu and San Nicholas Island, California, and Barking Sands, Hawaii. In addition, the Air Force supports the White Sands Missile Range, New Mexico, the Kwajalein Missile Range, and other DOD research and test facilities.

The Air Force and Navy operate JTWC, which moved to Hawaii in 1999. JTWC provides tropical cyclone warning services to DOD units and other United States subscribers in the area west of 180 degrees longitude to the East Coast of Africa in both hemispheres.

The Air Force directly supports DOD Special Strategic Programs, the National Command Authority, the National Military Command System, and the National Security Agency. Tailored environmental support products are disseminated to these customers worldwide.

The Air Force also provides agrometeorological output to the USDA's Foreign Agricultural Service and other national customers. The output provided includes diagnostic soil hydrology and other meteorological output pertinent to crop growth and yield estimation.

AFCCC provides climatic data and specialized studies to support the Air Force, Army, and other government agencies. Typical support satisfies requirements for assessments of natural environmental effects on military plans, weapon systems, facilities, and intelligence activities. AFCCC collects environmental data from AFWA and then sorts, checks, stores, and employs these data to produce tailored products. AFCCC is co-located with the National Climatic Data Center to facilitate cooperation and data exchange. AFCCC typically collects, quality assures, and applies worldwide surface and upper air observations, a three-dimensional (3-D) cloud analysis extracted from meteorological satellite imagery (Real-time Nephanalysis), a global analysis of snow cover, solar, geomagnetic, and space observations and indices, and many other specialized environmental data sets.

The Air Force Director of Weather is the DOD Modeling and Simulation Executive Agent (MSEA) for the Air and Space Natural Environment (ASNE). The director executes his responsibilities through the Office Chief co-located with AFCCC. The Executive Agent is responsible to ensure modeling and simulation developers and users have environmental models, algorithms, and data to represent the air and space environment rapidly, thoroughly, accurately, and consistently in a manner that promotes cost-effectiveness, ready access, interoperability, re-use, and confidence.

SPACE ENVIRONMENTAL SERVICES

The 55 SWXS has been the DOD focal point for space environmental support and the transition to AFWA of the strategic functions of the 55th will be completed during FY 2002. The 55 SWXS currently oversees six solar observatories located throughout the world and participates with NOAA in the operation of NOAA's Space Environment Center.

Many DOD systems are affected by space weather phenomena that occur in the near-Earth environment. Space weather impacts fall in three general categories: electromagnetic radiation, high-energy charged particles, and electrically charged particle clouds. Figure 3-DOD-3 includes information on the arrival times, duration, and effects of these events. AFWA provides a suite of automated and manually tailored space weather products to the range of customers susceptible to these impacts.

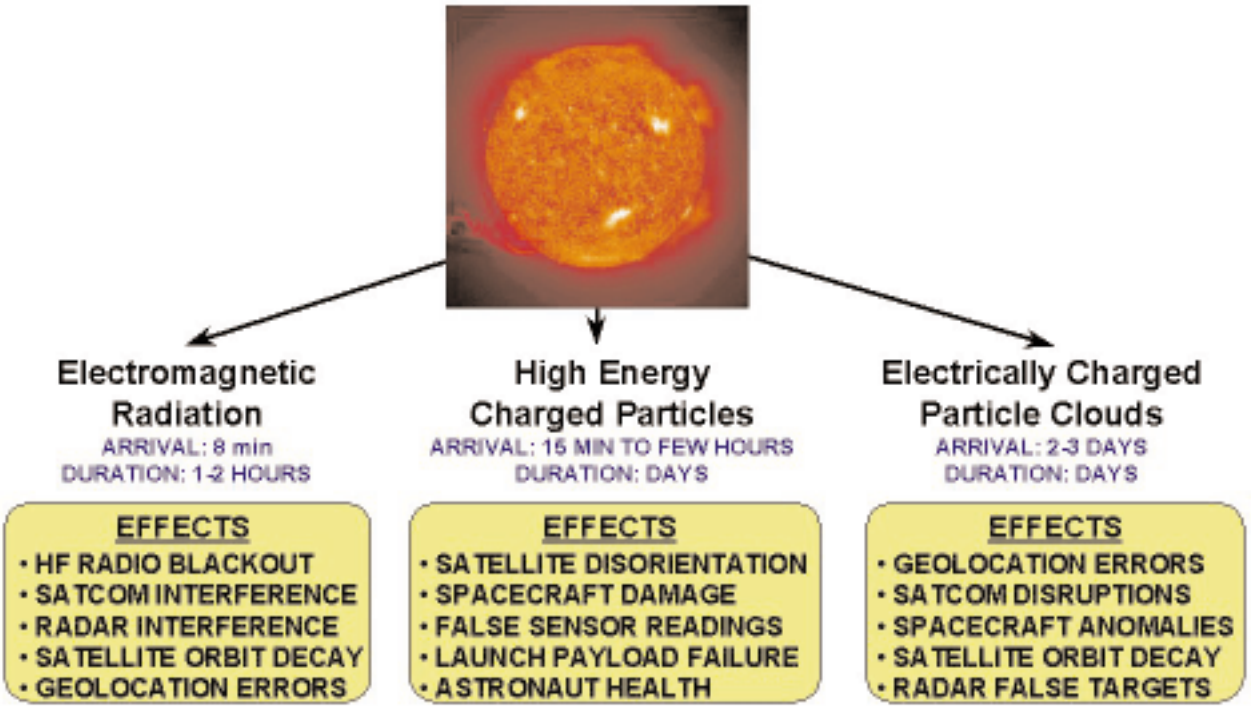


Figure 3-DOD-3. Solar activity produces radiation and particle effects in the near-Earth environment which affect military operations.

Sources of Space Environmental Information. A variety of ground- and space-based space weather data is available to forecasters providing space weather support.

The 55 SWXS operates a network of solar optical and radio telescopes at Sagamore Hill, Massachusetts; Ramey, Puerto Rico; Holloman AFB, New Mexico; Palehua, Hawaii; San Vito, Italy; and Learmonth, Australia. These systems provide observations of solar phenomena at optical and radio wavelengths.

A worldwide (primarily Northern Hemisphere) network of ground-based ionosondes and other sensors provide ionospheric data. AFW manages the automated Digital Ionospheric Sounding System (DISS) to provide measurements of disturbances in the ionosphere. The Jet Propulsion Laboratory also operates a complementary global network of sensors providing ionospheric data and the United States Geological Survey (USGS) operates a network of magnetometers. The USGS data provides indirect measurements of the strength of ionospheric and magnetospheric electric currents which create their own magnetic field superimposed upon the Earth's magnetic field.

The Geostationary Operational Environmental Satellite (GOES) vehicles provide real-time solar X-ray, electrically charged energetic particle, and geomagnetic data, made available through the SEC. DMSP, NOAA, and other DOD geostationary satellites provide additional energetic electrically charged particle data in low-Earth and geosynchronous orbits. Additionally, AFW leverages space-based data from NASA and other agencies. For example, NASA's Advanced Composition Explorer satellite provides real-time solar wind data.

A number of additional sensors or improvements to existing space weather sensors are planned. The Solar X-Ray Imager (SXI) recently went into orbit aboard GOES-12. The SXI will monitor solar emissions in the extreme ultraviolet (EUV) and X-ray portions of the solar spectrum. AFW expects the first Solar Radio Burst Locator (SRBL) to become operational in 2002 to provide radio wave measurements of the Sun while also mapping certain solar phenomena blocked from optical view by cloud cover. AFWA has additional improvements scheduled for the optical telescopes as well as for the ionospheric sensors.

AFWA uses a suite of space weather models to specify current solar or global characteristics of space weather where observations are not available and to assist in forecasting future conditions. These models use available observations and and include both climatology-based and physics-based algorithms.

More detailed descriptions of both the available observations and current models are available in Chapter 2 of the *National Space Weather Program Implementation Plan*, Second Edition, available from OFCM.

Mainstreaming Space. AFW initiated an effort in FY 2001 to mainstream space weather for both the providers and users and will continue this effort in FY 2002. DOD's increasing reliance on space weather-affected systems, continuing expansion of operations into space, and the Air Force's designation as executive agent for space indicates space weather support will become increasingly important. AFW will treat space weather initiatives the same as terrestrial weather initiatives and the spectrum of weather information users should think of space weather as quickly as they do terrestrial weather. The AFW goal is to create a seamless, real-time depiction of the entire natural environment from the mud to the Sun. The realignment of the 55 SWXS is part of this effort as well as the planning, programming, and budgeting for space weather initiatives following the National Space Weather Program and National Security Space Architect space weather architecture. AFW is taking steps to standardize support, improve space weather training for both providers and users, integrate dissemination channels for both space and terrestrial weather, and improve customer interaction. To improve interaction, AFW in conjunction with the AF Flight Standards Agency (AFFSA) is modifying the flight weather briefing form to include space weather effects on navigation and communication and establishing a space weather "pilot report" process to obtain feedback to identify, quantify, and archive space weather impacts.

SUPPORTING RESEARCH

The overarching objective of the Air Force meteorological and space environmental R&D program is to provide system designers, operational weather support personnel, and weather information users with the technology and tools to gain and maintain the advantage over a potential adversary. Documented R&D requirements in the atmospheric sciences are articulated in the AFW Mission Support Plan and in the Mission Area Plans of the Air Force major commands. Space environment R&D is targeted to meet the DOD's space weather requirements as summarized in the *National Security Space Architect's Space Weather Architecture Study* and the associated *Transition Plan* as well as the *National Space Weather Program Implementation Plan, Second Edition.*

In meteorological R&D, the AF is improving numerical weather prediction, studying such problems as optical turbulence, and has transitioned key advances in tactical decision aids into operations, permitting improved forecasting of electro-optical system performance and generation of cloud and target scene visualizations for training, system development, and mission rehearsal. More detailed information on weather impact decision aids was

provided in this section of last year's Federal Plan. In addition to internal efforts, AFW will continue to rely on collaboration and leveraging of efforts with other federal meteorological agencies, research labs, and universities to meet supporting research needs.

Mesoscale Modeling for Air Force and Army Operations. Supporting research in the area of mesoscale numerical weather prediction continues to pay dividends. Recent research paid off in 2001 with the AFWA MM5 implementation of the Land Surface Model (LSM) to support Air Force and Army operations worldwide. The LSM analyzes the current state of the land surface to provide information to both DOD and civilian agencies and, through coupling with MM5, improves forecasting performance in the low levels. This allowed AFW to improve forecasting for low-level aircraft operations, trafficability for ground forces, dispersion of contaminants, and employment of precision guided munitions. The advances achieved in the LSM are also being carried over into Weather Research and Forecasting (WRF) model development, another area of AFWA participation in supporting research. AFWA is closely collaborating with NCAR, NCEP, FSL, and the University of Oklahoma's Center for the Analysis and Prediction of Storms (CAPS) in WRF development. WRF is the next generation community model expected to replace MM5, and AFWA is benefiting by leveraging the efforts of more than 200 registered users developing the model. AFWA is preparing to fully implement WRF operationally in the 2004 to 2005 timeframe and will continue in 2002 with sponsorship and funding of development at NCAR and FSL, test and evaluation of real-time runs of the WRF prototype, and will lead the LSM Working Group while participating in others.

Atmospheric Optical Turbulence. Electro-optical (EO) systems are adversely affected by optical distortions caused by atmospheric thermal or refractive turbulence. As the sophistication of current and next generation military systems grows, the requirement for more detailed knowledge of fine scale (meters or less) atmospheric behavior also grows. The Airborne Laser (ABL) program is one such system. Since the meteorological conditions that produce turbulence vary, the performance of such systems varies. The Air Force program in atmospheric optical turbulence measurements and modeling seeks to address these needs. Researchers used a balloon-borne turbulence sensor mated to a standard radiosonde (Figure 3-DOD-4) to obtain measurements, producing data and empirical models that are the basis for ABL system specification. Balloon-borne measurements were made in conjunction with airborne stellar scintillometer measurements to understand the relation between atmospheric structure and path-integrated optical effects. The turbulent scalar spectrum was also sampled using balloon-borne high-bandwidth sensors. As part of an international program, aircraft measurements of temperature and velocity turbulence have been made in different locales worldwide. Horizontal measurements by the aircraft augment the vertical profiling by balloons to assist in the development of the detailed knowledge to support new EO systems.

United States Weather Research Program (USWRP). AFW entered into discussions with USWRP in 2001 to explore expanded participation in the program and is looking forward to increased collaboration in 2002. USWRP's mission is to accelerate forecast improvements of high-impact weather and facilitate full use of advanced weather information. The program currently focused on landfalling hurricanes, heavy precipitation, and socio-economic impacts. AFW anticipates being able to leverage the advances made in the focus areas of landfalling hurricanes and heavy precipitation and is eager to leverage future efforts in the areas of observing and assimilation strategies in data sparse regions and urban forecast issues and opportunities. AFW is already committed to the USWRP-

Figure 3-DOD-4. An AF weather officer prepares a balloon for measuring atmospheric turbulence conditions as part of the airborne laser program. (US Air Force photo by Staff Sgt. Timothy Cook)

affiliated community development of the Weather Research and Forecasting (WRF) model and will continue to support this development during FY 2002. The basic WRF model is running at AFWA now and initial results are very favorable.

University Partnering for Operational Support (UPOS). AFW continued to collaborate through the UPOS program with the Johns Hopkins University Applied Physics Laboratory (JHU/APL), the University of Alaska at Fairbanks and its Geophysical Institute, and with the Army Research Laboratory (ARL). UPOS provides a link between university research and the DOD operational community and is currently focused on near-term forecasts of ground, tropospheric, ionospheric, magnetospheric, and solar weather. The goals of UPOS are to provide an alternate path for rapid transition of the best applied research ideas to the warfighter and to raise awareness of DOD operational needs within the academic community. The partnership delivers prototype operational products to the AF and Army sponsors. The UPOS Steering Committee, which includes the AF Director of Weather, meets approximately semiannually to review progress and select new projects as appropriate. UPOS includes warfighter exercise support to demonstrate utility of products through web-based, non-operational access as well as collecting direct user feedback for faster updates of the prototype systems. Some examples of tropospheric weather UPOS work include fine-scale polar numerical weather prediction, operational volcanic plume forecasting, and electromagnetic propagation forecast maps generated from MM5 output. Examples of space science work include high frequency radar and communication propagation to predict the area a transmitter can illuminate, forecasting coronal mass ejections, and improving determination of solar events which will cause militarily significant space weather effects on and near Earth.

Air Force Research Laboratory (AFRL). In other space weather research, AFRL programs focus on ionospheric impacts on RF systems, space particle specification and forecast, solar disturbance prediction, and neutral density effects on LEO spacecraft. Working closely with SMC/CI under a Memorandum of Agreement, AFRL supports the development and upgrading of operational space weather sensors, models, and software products to include space environment sensors on the DMSP spacecraft, state-of-the-art ground-based scintillation detectors, total electron content sensors, Digital Ionospheric Sounding Systems (DISS), the Improved Solar Observing Optical Network (ISOON), and the Operationalized Space Environment Network Display (OPSEND) suite of web-based products. AFRL also conducts customer-supported R&D for NPOESS, the Defense Modeling and Simulation Office (DMSO), the National Reconnaissance Office (NRO), the Ballistic Missile Defense Office (BMDO), the DOD High Performance Computing Modernization Office (HPCMO), and NASA. More detail on AFRL's space weather research is well documented in this section of last year's Federal Plan and this program will continue in 2002 to build improvements for future operational implementation.

In addition to the AFRL research portfolio, AFW collaborates with others in the space weather community to develop new techniques, models, and systems for transition to operational applications. These include the Community Coordinated Modeling Center, the Constellation Observing System for Meteorology, Ionosphere, and Climate, and the University Partnering for Operational Support mentioned previously.

Community Coordinated Modeling Center (CCMC). AFW is a full member of the consortium that formed the CCMC in 2000, co-chairs the CCMC Steering Committee, and supported center efforts in 2001 by providing Defense Research and Engineering Network (DREN) connectivity and exclusive access to a set of supercomputing nodes at AFWA. The CCMC mission is to provide a computing facility to enable, support, and perform research for the next generation of space weather models, preparing them for transition to operations through the rapid prototyping centers at both NOAA's SEC and the Air Force. The CCMC provides a place where researchers can try out space weather models in a large-scale computing environment, explore integration with other models, and structure their code to ease transition to operations. The center currently plans to deliver the first model, a 3-dimensional magneto-hydrodynamic magnetospheric model, to the rapid prototyping centers in September 2001. Sponsoring agencies are also planning a CCMC Workshop early in FY 2002 to explore future research activities for the center. AFW will continue to support the CCMC in FY 2002 but is examining alternatives to the increasing cost of maintaining the computing nodes dedicated to the CCMC. Additional information on the center is available at its web site at *http://ccmc.gsfc.nasa.gov/* (Figure 3-DOD-5).

Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC). AFW, through the Air Force Office of Scientific Research (AFOSR), will continue to collaborate with UCAR, NOAA, NASA, NSF, and the Navy on the COSMIC program. COSMIC comprises six micro-satellites planned for launch in 2005 to provide approximately 3,000 daily global observations of pressure, temperature, humidity, refractivity, ionospheric electron density, and ionospheric scin-

tillation. The system will use GPS occultation techniques to provide vertical atmospheric soundings as well as an ionospheric photometer and a triband beacon to measure electron densities and ionospheric parameters. The global coverage of atmospheric profiles should improve global-scale numerical weather prediction models as well as more limited value in regional models and point analysis models. The space weather observations will complement other sensors to provide a more complete picture of the ionosphere and improve prediction of communication and navigation degradations. Additional information on COSMIC is available at *http://www.cosmic.ucar.edu*.

In conclusion, through a continuous process of review and definition, the AF documents its requirements for supporting research aimed ultimately at providing timely, accurate, and relevant weather information to the warfighter today and in the future. In meteorological R&D, AFW is committed to continued development of the WRF model and collaboration with others to the benefit of the warfighter and the nation overall. Space weather research will continue with a strong program in 2002 both in AFRL as well as in leveraged programs such as UPOS and the CCMC to speed needed capabilities to operations at minimum expense.

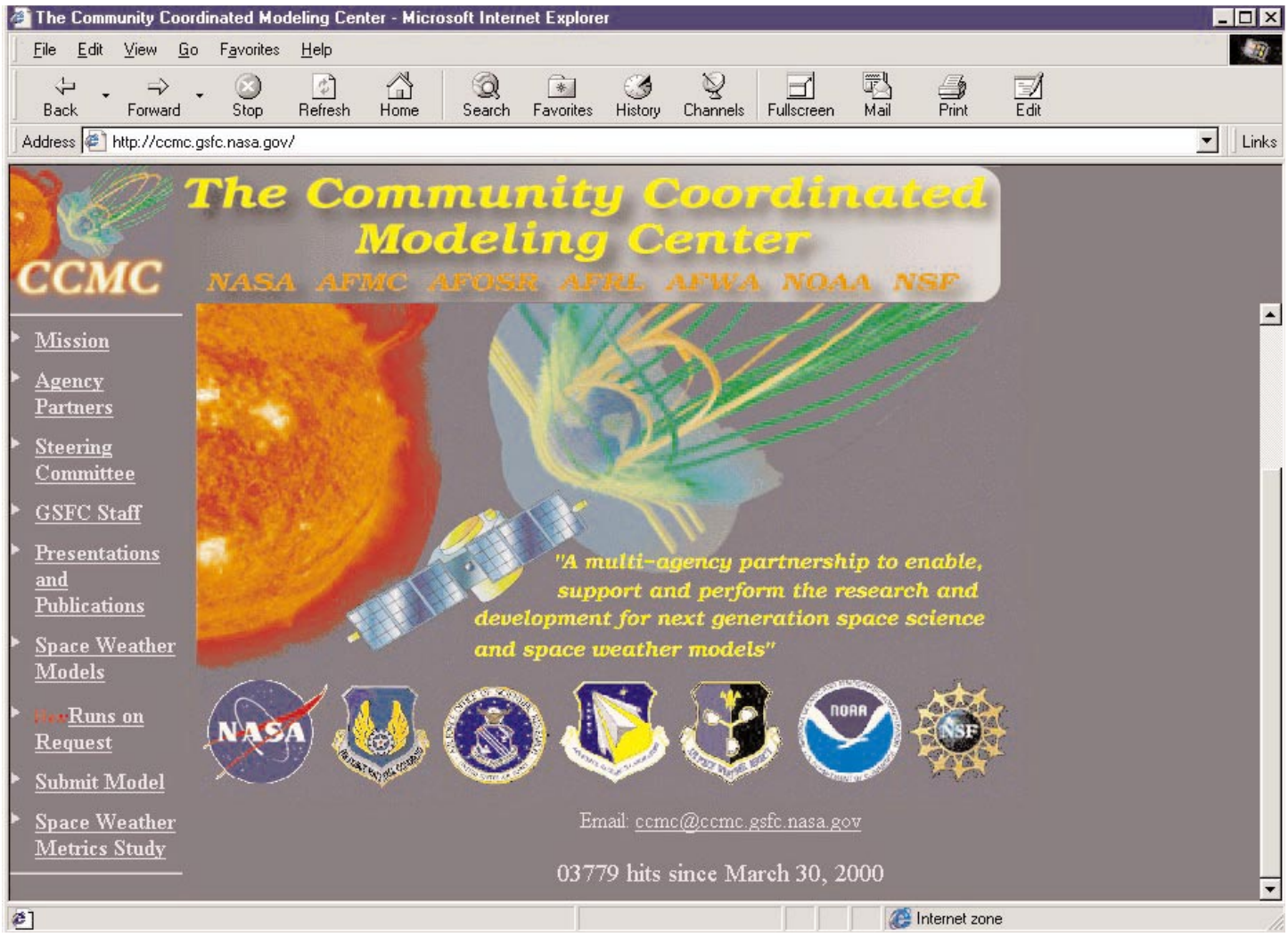


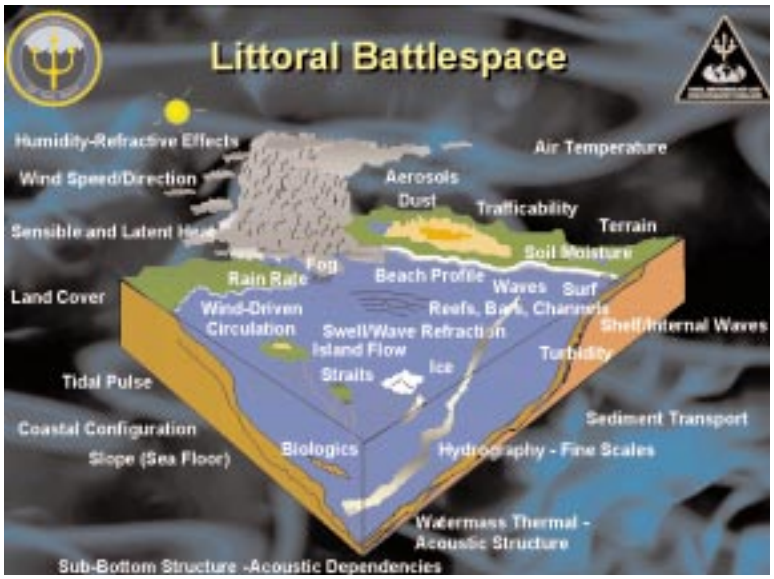
Figure 3-DOD-5. The home page of the Community Coordinated Modeling Center provides information on the center as well as access to research model output. (See text for URL.)

PROGRAM OVERVIEW

The United States Navy has the unique military requirement to assess meteorological and oceanographic (METOC) impacts on naval, joint, and combined operations. METOC support begins by measuring the battlespace physical environment and culminates with safe, effective weapons systems and sensor employment. The perspective is global and historically focuses on areas outside of the contiguous 48 states, but the emphasis is wherever the fleet goes and includes force protection within the coastal waters of the United States. Developing METOC forecasts and determining potential effects on weapons system information requires:

- the collection of data through tactical and dedicated sensors (including satellites);
- fusion and analysis of atmospheric and oceanographic phenomena; and
- meteorological information in tactical decision aids and mission planning systems.

The Chief of Naval Operations, through the Oceanographer of the Navy (CNO(N096)), sponsors operational Navy METOC services and related research and development (R&D). The Navy provides meteorological services for Navy and joint forces, meteorological products to the USMC, and oceanographic support to all elements of DOD. The Oceanographer of the Navy sponsors programs in four closely related disciplines to provide worldwide, comprehensive, integrated weather and ocean support - meteorology, oceanography, geospatial information and services, and precise time and astrometry. All are used to protect ships, aircraft, fighting forces, and shore establishments from adverse ocean and weather conditions, and to provide a decisive tactical or strategic edge by exploiting the physical environment. Early in 2001, the Oceanographer of the Navy was named the "Navigator of the Navy." He serves as the Chief of Naval Operations' focal point for the development of technical standards for navigation plans, data standards, training, and navigation system certification. He also serves as an advocate and broker for all fleet navigation issues. The Oceanographer of the Navy also recently streamlined his staff's organizational structure to better respond to fleet needs. The Oceanographer of the Navy's websites are at *www.oceanographer.navy.mil* and (for navigation information) *www.navigator.navy.mil*.



Research and development is conducted by warfare centers, laboratories, and systems commands, through sponsorship by the Chief of Naval Research and the Oceanographer of the Navy. To ensure that all research and development supported by the Oceanographer is in direct support of the Naval mission as established by formal Navy doctrine, the Oceanographer recently developed and implemented a comprehensive framework to transition research to operations. The Naval Research Laboratory (NRL) and the Space and Naval Warfare Systems Command (SPAWARSYSCOM) are the primary activities that manage naval research and transition to operations, and are supplemented by various universities, industry partners, and organizations under Navy contract. NRL detachments are collocated with the Fleet Numerical Meteorology and Oceanography Center in Monterey, California and with the Naval Oceano-graphic Office at Stennis Space Center, Mississippi. The SPAWARSYSCOM METOC Systems Program Office (PMW-155) is Navy's single program manager for METOC system development and acquisition.

METEOROLOGICAL SERVICES

UNITED STATES NAVY

Operational support within the Navy is provided by elements of the Naval Meteorology and Oceanography Command (NAVMETOCCOM). Navy METOC activities are involved in worldwide collection of observations ashore, afloat and through remote sensors, and in the assimilation and processing of these observations on a global basis to support analysis and forecasting throughout the world.

The Fleet Numerical Meteorology and Oceanography Center (FLENUM-METOCCEN), in Monterey, California, provides global, regional, and tactical observations, analyses, and coupled air-ocean forecasts. Environmental data is acquired through links with DOD and National Oceanic and Atmospheric Administration (NOAA) conventional and remotely sensed data distribution systems. By agreement between Navy and Air Force, FLENUMMETOCCEN

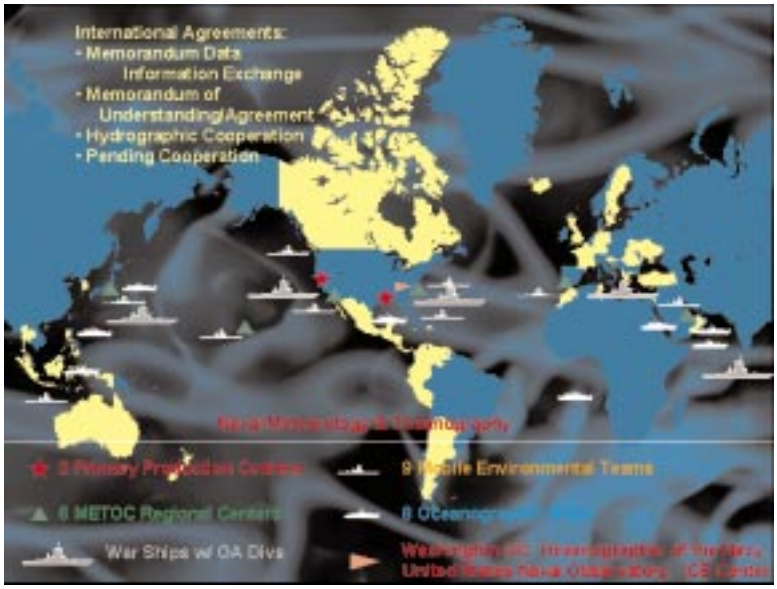


Figure 3-DOD-6. Global locations for United States Navy theater and regional support

is the primary DOD global numerical weather prediction center, running the Navy Operational Global Atmospheric Prediction System (NOGAPS), developed by the Naval Research Laboratory's Marine Meteorology Division, also in Monterey. NOGAPS provides global atmospheric predictions and drives a variety of ocean models, including the global Wave Watch III ocean wave model run at FLENUMMETOCCEN.

In near-shore regions, the small-scale interactions between the atmosphere, underlying ocean, and nearby land make it necessary to analyze and predict the battlespace environment with higher resolution and improved physics. In addition to the global product suite, FLENUMMETOCCEN is uniquely capable of providing high resolution coupled air-ocean products on short notice for any location in support of global contingency military and humanitarian operations. Navy's Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS) is an operational tactical system featuring data quality control algorithms; nested, non-hydrostatic physics; explicit moisture physics; aerosols; and improved data assimilation. Using lateral boundary conditions provided by NOGAPS, COAMPS provides a high-resolution, re-locatable, METOC prediction capability to support joint littoral operations. COAMPS is routinely run for Europe, Southwest Asia, Western Pacific, Central America, Western Atlantic, the continental United States, and the Eastern Pacific. COAMPS is frequently run in other areas around the world as requirements dictate.

NOGAPS and COAMPS forecast products are distributed via various communications systems including the Internet, either directly to Fleet customers or through the Navy regional METOC centers. The regional METOC centers develop value-added products and services tailored to specific operational requirements. COMNAVMETOCCOM recently installed computer systems at all their regional centers to run COAMPS in theater, allowing them to respond to Fleet commanders' requirements in near real-time. As a complement to numerical forecast products, FLENUMMETOCCEN provides atmospheric and oceanographic observations, satellite products, data extracts, and data for tactical decision aids. Additionally, FLENUMMETOCCEN is the designated National Center of Excellence for remotely sensed microwave products under the Air Force/Navy/NOAA Shared Satellite Processing Agreement. The FLENUMMETOCCEN web site is *www.fnmoc.navy.mil*.

Since atmospheric conditions are inherently coupled to oceanographic conditions, the Navy's program in meteorology is closely linked with oceanography, the focus of the Naval Oceanographic Office (NAVOCEANO), Stennis Space Center, Mississippi. NAVOCEANO's primary responsibilities include the collection, processing, and distribution of oceanographic, hydrographic, and other geophysical data and products. NAVOCEANO recently began disseminating products from the world's first operational global layered ocean model - NLOM. NAVOCEANO is the Navy's primary processing facility for NOAA polar-orbiting satellite data and is the National Center of Excellence for satellite-derived sea-surface temperature measurements providing the global sea surface temperature data critically important to successfully running NOGAPS and COAMPS. Additionally, NAVOCEANO is a DOD Major Shared Resource Center, enabling creation of the latest research and development models on the most modern scalable supercomputing architecture and facilitating transition from R&D to operational use. The NAVOCEANO web site is *www.navoceano.navy.mil*.

Tailored Theater and Regional Support

Theater and regional support are provided to forces ashore and afloat through six regional centers delivering METOC services within their broad areas of responsibility (AORs). Aligned with specific Naval Component Commanders of the Unified Commanders-in-Chiefs (CINCs), these centers tailor services to theater requirements, and manage and prioritize dissemination of numerical products from FLENUMMETOCCEN and NAVOCEANO (Figure 3-DOD-6). Special products needed to meet requirements of Joint

Force Commanders are also generated by the regional centers. Additionally, the Joint Typhoon Warning Center (JTWC) (operated by Navy and Air Force) is co-located with the Naval Pacific Meteorology and Oceanography Center in Pearl Harbor, Hawaii. Specific METOC products common to the regional centers include high winds and seas warnings for the world's oceans, tailored forecast support for Navy, Coast Guard and NOAA ships at sea, and ship routing services for ocean transits.

Tailored ice forecasts and analyses are provided to DOD by the Naval Ice Center (NAVICECEN), located in Suitland, Maryland. The Navy (through NAVICECEN), NOAA, and the United States Coast Guard, jointly operate the National Ice Center (NIC). The NIC provides ice analyses and forecasts for the Arctic and Antarctic regions, coastal United States waters, and the Great Lakes to civil as well as military activities.

Local and Aviation Support

NAVMETOCCOM Facilities at Whidbey Island, Washington, Naples, Italy and at Jacksonville and Pensacola, Florida, provide aviation forecast services as well as Fleet Operating Area (OPAREA) and local forecasts and warnings for aircraft, ships, submarines and naval bases and staffs. Additionally, there are 31 NAVMETOCCOM detachments worldwide. Though primarily situated at Naval Air Stations for aviation safety of flight forecasting, several are located at Naval Stations in support of sea-going units. The detachments provide METOC forecasting and warning services to DOD and allied units within their local and functional areas of responsibility (Figure 3-DOD-7). Detachments and Facilities within the continental United States use numerical products from both FLENUMMETOCCEN and NOAA's National Centers for Environmental Prediction (NCEP). Overseas Detachments and Facilities use FLENUMMETOCCEN numerical products, in addition to AF and foreign products. Additionally, Fleet Numerical provides aircraft routing services for military (primarily Navy) aircraft on demand.

Two detachments provide specific technical services: one, at the National Climatic Data Center, Asheville, North Carolina, coordinates the Navy's climatological program as part of the Federal Climate Complex. The detachment, at Tinker AFB, Oklahoma, manages Naval data requirements for the AF Automated Weather Network (AWN).

On-Scene Support

The Navy's permanent afloat METOC assets are their OA Divisions, embarked aboard aircraft carriers, major amphibious ships and command ships. The OA division's primary objectives are safety of ships, aircraft and embarked personnel, optimum tactical and planning support to on-board warfare commanders, and tailored on-scene products and services for the assigned task force/group and Allied units in joint, combined, or coalition military and humanitarian operations. The primary source of on-scene Navy METOC support for other forces afloat and those deployed ashore are deployable Mobile Environmental Teams (METs). These teams provide short-term, on-scene services to DOD activities without organic METOC personnel, other government agencies, and elements of the armed forces of allied nations during combined exercises or operations. METOC products and services provided by these teams are tailored to each units' requirements and include tactical METOC information and forecasts for operations, weapon and sensor system employment and tactical decision making, and climatological information for long-range planning.

UNITED STATES MARINE CORPS (USMC).

On-Scene METOC forecasts are vital to the operation of the USMC. The Deputy Chief of Staff for Aviation, Headquarters, United States Marine Corps (Code ASL37) is the cognizant office for Marine Corps METOC support and requirements. The Marine Corps weather organization consists of two operational chains of command, one for garrison aviation weather units and the other for the Fleet Marine Force (FMF) (Figure 3-DOD-8).

Figure 3-DOD-7. SH-60 Seahawk rotors illuminated by sparks from blowing sands off Kuwait.

Figure 3-DOD-8. Marines launch reconnaissance craft from USS Austin (LPD 4) near Croatia. Small craft are especially susceptible to heavy seas.

Garrison aviation weather units at Marine Corps Air Stations (MCAS) and Facilities (MCAF) are manned by USMC personnel and provide direct aviation weather support to host and tenant units. Integral to Marine Corps aviation activities, these weather units provide services to assigned activities and organizations, which include nine major air stations in the continental United States, one in Hawaii, and two in Japan.

Marine Corps METOC support activities are assigned to the FMF in the Aviation Combat Element (ACE) of the Marine Air Ground Task Force (MAGTF). ACE METOC support is derived from the Marine Wing Support Squadron (MWSS) within the parent Marine Aircraft Wing (MAW). The existing 10 MWSS METOC activities are equipped to provide support at a bare-based or expeditionary airfield by deploying the Meteorological Mobile Facility (METMF). Additionally, Meteorological Support Teams (MSTs) from the ACE MWSS can be assigned in direct support of the Command Element, Ground Combat Element, and Combat Service Support Element of the MAGTF, and may augment a Marine Expeditionary Unit and Joint/Combined METOC Forecast Unit.

MAJOR METOC SYSTEMS

The capability to provide near real-time global, regional, and local METOC services to the Navy and Marine Corps team requires a robust and evolving set of leading edge technology tools. Theses tools are embodied in the following systems:

Primary Oceanographic Prediction System (POPS) II Upgrade. The Primary Oceanographic Prediction System (POPS II U) operates complex computer-based models of the world's ocean and atmosphere and disseminates METOC forecasts, charts, imagery and operational data sets to support deployed Navy and DOD forces worldwide. This data is essential to the safety and effectiveness of the Navy's operational platforms, sensors, and weapons including cruise and ballistic missiles, ships, aircraft, radar and sonar. POPS II U prediction models must provide horizontal resolutions of 1-5 kilometers and in near real time for use in on-scene tactical decision aids and systems.

POPS II U is the DOD approved system that operates global, regional, and tactical atmospheric, oceanographic, ice, wave, and tropical cyclone models (Figure 3-DOD-9). The POPS II U, located at FLENUMMETOCCEN also provides the computing capability required to support DOD's only global atmospheric forecast model under an agreement between the Navy and Air Force. Under an umbrella memorandum of agreement signed in 1993 between NOAA and FLENUMMETOCCEN, both sides will provide cooperative efforts in operational numerical modeling, data exchange, and mutual backup between NCEP and FLENUMMETOCCEN. In 1999, FLENUMMETOCCEN provided numerical modeling backup capability to NCEP for two Atlantic hurricanes and for a five month duration after the NCEP computer-fire outage in October.

POPS II U is composed of a number of different high-performance computer systems, including a SGI Origin 3000 (512 processors) and two Origin 2000s (128 processors). By the end of Phase 1 (FY 2001), POPS II U will have replacement hardware and software that forms the basis of METOC support throughout DOD. This capability includes state-of-the-art decoders, data managers, quality control algorithms, and observational assimilating software for all types of METOC data from all available sensors. These data will support state-of-the-art numerical weather, ocean, chemical/biological, and acoustic models, run in multiple nested fashion from global scale models at resolutions of tens of kilometers to battlegroup/battlefield models at resolutions of a few kilometers.

The POPS system performance improvement objectives will support DOD in the following specific ways:

a. Improved METOC forecast skill worldwide at increasingly longer time periods
b. Optimal aircraft routing services
c. Safe and direct ship routing services
d. Hurricane, cyclone, and tropical storm prediction worldwide
e. Open ocean and coastal wave prediction

f. Precipitation prediction
g. Refractivity conditions/ducting range
h. Acoustics support
i. Ballistic missile targeting support
j. Search and rescue
k. Low level chemical/biological/ nuclear transport prediction

Distributed Atmospheric Modeling Prediction System (DAMPS). For centuries, military commanders have looked to the weather for tactical advantage. The Navy is currently the nation's only military service that operates a distributed model in support of tactical weather prediction. DAMPS allows users to ingest high-resolution data and on-scene observations into regional and global model information received from the Fleet Numerical Meteorology and Oceanography Center in Monterey, California. The result is an on-scene weather model that provides accurate weather predictions for an operating area within a 24-hour timeframe.

DAMPS is fielded at all Navy METOC centers worldwide and uses the COAMPS model to develop METOC prediction products out to 48-hours. DAMPS uses real-time weather data from ship and battle group observations, including parameters such as: wind, temperature, cloud, visibility and radar data, and then incorporate this data into its analysis. This analysis can be highly focused on any area of interest.

Tactical Environmental Support System (TESS). The Navy is presently undergoing migration towards a modular, interoperable suite of systems to ingest, process, fuse, display, and disseminate METOC data. The program consists of five seamless versions known as the Naval Integrated Tactical Environmental Subsystem (NITES) versions I-V. NITES systems will be fielded in FY 2000 through FY 2004. The five NITES versions are:

- NITES I. Provides Navy decision-makers on major combatant ships with METOC assessments and forecasts, and integrates data with sensor and weapon platform parameters for system performance assessments. Theater METOC Centers use NITES I to provide value-added products to fleet units, and the numerical prediction guidance generated by FLENUMMETOCCEN.
- NITES II. Makes METOC data and products available to Navy and Marine Corps activities afloat and ashore via the Global Command and Control System-Maritime (GCCS-M). TESS data and products are used to feed tactical decision aids resident within GCCS-M. NITES II is the basis for the Joint METOC Segment of the new Global Command and Control System (GCCS) V3.0.
- NITES III. An unclassified forecast, briefing, and display system tailored to Naval METOC shore activities in support of aviation operations.
- NITES IV. A portable system tailored to Mobile Environmental Team (MET) and USMC Meteorological Support Team (MST) METOC requirements. Fielding of NITES IV is expected to commence in FY 2003.
- NITES V. A forecast, briefing, and display system for foreign military sales to ensure interoperability with our allies. It is a follow-on to the Allied Environmental Support System (AESS) and will incorporate capabilities used in the other NITES variants.

Tactical Environmental Data Server (TEDS). TEDS is a storage and data management system for METOC information. It is the central engine in both the Tactical Environmental Support System (TESS) and the Navy Integrated Tactical Environmental System (NITES), providing the broadest support via access to the full spectrum of client applications and METOC models. TEDS architecture connects to government historical databases and commercial relational databases management systems (RDBMS) using network and Internet protocols. With the associated METCAST automated delivery software, users with Internet access can monitor information updates on demand, continuously, or on schedule.

Meteorological Data Receiver-Recorder (AN/SMQ-11). AN/SMQ-11 is the principal Navy system to acquire environmental data directly from satellites. There are different equipment configurations for ships and shore sites, and through their interface with

Figure 3-DOD-9. USS KETCHIKAN (YTB 975) run aground by super typhoon in Guam.

TESS variants they provide remotely sensed information to the operator.

Automated Surface Observing System (ASOS). ASOS supports aviation and local area observing requirements at Navy and Marine Corps stations worldwide, leveraging development efforts of the National Weather Service (NWS). ASOS helps assimilate field meteorological parameters and facilitates efficient entry of surface aviation observations and synoptic weather reports into the Automated Weather Network (AWN).

Supplemental Weather Radars (SWR) (AN/FPS-131 and AN/TPS-76). The Navy has procured Supplemental Weather Radars to provide Doppler weather radar coverage at selected Navy and USMC sites, mostly overseas, outside of NEXRAD coverage. This system replaced the obsolete AN/FPS-106 non-Doppler weather radars.

Meteorological Mobile Facility Replacement (METMF(R)). The METMF(R) is a transportable system that houses meteorological support equipment for the Marine Air Ground Task Force (MAGTF). This 8x8x20 foot van provides a fully functioning weather office designed to support Marine Corps expeditionary airfield operations for 30 days without resupply. It includes sub-systems for data collection (local, remote and upper air sensors), data processing, satellite data ingest and display, Doppler radar, communications, briefing support, and support for remote forces. The METMF(R) is interoperable with the Marine Corps C^{4}I systems and METOC systems of the other Services via the Global Command and Control System (GCCS).

Operational Products and Services

Optimum Track Ship Routing (OTSR), and Optimum Path Aircraft Routing System (OPARS) are advisory services for fleet units. They are based on NOGAPS, COAMPS and wave forecast data, are tailored to the customer, and provide guidance to the forecaster for the safe operation and cost-effective routing of DOD ships and aircraft as they have for nearly 30 years (Figure 3-DOD-10). OTSR and OPARS save the operating forces of all services approximately $57 million per year in reduced fuel consumption and personnel costs.

The Navy Oceanographic Data Distribution System (NODDS) is a PC-based software package originally developed in 1982 to make FLENUMMETOCCEN numerical products available to front line DOD users. All standard METOC fields, synoptic observations and basic DMSP satellite imagery is also available. NODDS has been made available to non-DOD Federal agencies and others in the civilian community through an earlier agreement between Navy and NOAA, but is now being phased out in favor of Web-based display capabilities.

The Joint METOC Viewer (JMV) is a more recent capability that is integrated into NITES and is gradually replacing NODDS. Building on the availability of the Internet and the successful user interface of NODDS, JMV provides an intuitive Graphical User Interface for retrieving, viewing and annotating METOC information. Authorized DOD and Government users with Internet access now have a simple, cost-efficient way to display weather and ocean information on various computer platforms and operating systems. JMV is operational at several hundred DOD and other government sites including ships, and is available to authorized non-government users as well.

WxMAP ("Weather Map") is a new Web-based service from Fleet Numerical which allows military and civilian users worldwide to access numerical output of selected weather parameters at pre-established geographical areas throughout the world. Because of continually emerging Internet technology, a large subset of these products can also be made available to the general public at no additional cost.

Since 1983, the Naval Regional Meteorology and Oceanography Center, in Norfolk Virginia has provided long range forecasts in support of Energy Conservation efforts at Naval shore installations in the continental United States. The services are primarily in the form of extended-range (10 day) temperature forecasts provid-

Figure 3-DOD-10. Waves crash over the 65-foot-high bow of the aircraft carrier JOHN C. STENNIS (CVN 74).

ed to energy managers to assist in optimizing power plant operations. Monthly temperature/degree day outlooks and long-lead (12 month) seasonal and precipitation forecasts are also issued to assist in strategic planning of fuel purchasing and resource allocation. Documented savings from the Energy Conservation Forecast Program exceed $62 million, with the majority of savings resulting from power plant steam/air conditioning on/off recommendations and energy resource/fuel allocation based on long-lead forecast products. Customers include 128 Navy and Marine Corps facilities and commands.

SUPPORTING RESEARCH

The Navy administers a diverse research and development (R&D) program, ranging from software development to sensor engineering, and processing, display, and distribution devices. Application of R&D activities of other Services and Federal agencies is always considered, and use of existing government and commercial off-the-shelf items is emphasized.

The Navy is a world leader in the field of numerical weather prediction for marine environmental services. Transitioning fundamental scientific research, through additional development, into operational METOC models is key to a successful numerical prediction program. This ongoing process includes work at universities and the Naval Research Laboratory's Marine Meteorological Division to keep the NOGAPS and the COAMPS at the leading edge of technology. Development is also underway to improve data assimilation, quality control, and management techniques to support these models. A major numerical weather prediction thrust is underway to develop a shipboard tactical atmospheric forecast capability to assimilate locally acquired data in real time and deliver high resolution (5 km), limited area (100s of km), short range (12-24 hr) atmospheric predictions in tactical timeframes.

The Navy R&D program in remote sensing develops techniques to extract tactically significant information in the littoral regions of the world. Sensors aboard existing satellites are exploited to the greatest extent possible and plans are in place to incorporate new capabilities when introduced. Because many satellite processing algorithms are designed for use with tactical systems, expert or rule-based processes are used where possible to reduce human-intensive interpretation.

ONR and SPAWARSYSCOM continue to explore techniques for assimilating environmental data through non-traditional sensors. One such effort is investigating the AEGIS Weapon System's AN/SPY-1 radar and developing the ability to produce NEXRAD-like radar information from ships at sea.

INTERAGENCY COOPERATION

Navy and Air Force have long been cooperating in DOD weather support, and these efforts have led to such successes as the Defense Meteorological Satellite Program and the Joint Typhoon Warning Center. Recently, the two services have reinvigorated efforts to increase efficiencies in their METOC programs through greater cooperation. The NAVAF-21 Charter, signed in June 1999 by the Oceanographer of the Navy and the Air Force Director of Weather, expands on the 1992 NAVAF Agreement for long-term cooperation in DOD operational METOC efforts. NAVAF-21 implements mechanisms to formalize information exchange and cooperation, focus limited resources and prioritize issues to most efficiently meet long-term DOD METOC requirements, and establish an enduring methodology for documenting and periodically reviewing decisions on areas of mutual interest.

To maximize efficiency and benefit for Navy and NOAA cooperative activities, an Umbrella Memorandum of Agreement (MOA) between these two agencies was signed in 1993. Additionally, an agreement for shared processing of remotely sensed data was last updated in 1997. Both agencies continue to identify new areas of cooperation and review existing agreements for conversion into annexes to this MOA. Specific areas include:

- Cooperative efforts in operational numerical modeling, data exchange, and mutual backup between FLENUMMETOCCEN and the NCEP.
- Navy/NOAA/Coast Guard operation of the National Ice Center.
- Cooperative efforts between FLENUMMETOCCEN and the Pacific Fisheries Environmental Laboratory of the National Marine Fisheries Service
- Air Force Weather Agency (AFWA)/Navy(FLENUMMETOCCEN, NAVOCEANO)/NOAA-NESDIS agreement on shared processing of satellite data.
- Navy/NOAA agreement on ASOS procurement and installation.
- Satellite altimetry data processing.
- Training cooperation through Cooperative Program for Operational Meteorology Education and Training (COMET).

MOAs also exist between the Department of Commerce (DOC), Department of Transportation, and the DOD concerning procurement and operation of NEXRAD. Additionally, Navy is a DOD participant in the development of the DOC/DOD/NASA converged National Polar-orbiting Operational Environmental Satellite System (NPOESS).

NATURAL DISASTER MITIGATION

Navy METOC plays a vital role in reducing the impact of natural disasters to units both ashore and afloat. Severe weather warnings are issued at Naval facilities by the local NAVMETOCCOM activity when conditions war-

rant. For ships operating at sea without METOC personnel embarked, tailored enroute weather forecast messages (WEAX) and high winds and seas warnings provide commanding officers with advance notice of heavy weather, and Optimum Track Ship Routing (OTSR) forecasters monitor ship movements and provide heavy weather avoidance recommendations.

Tropical cyclones and even severe winter storms provide even greater challenges, as ships cannot generally "ride out" storms in-port without sustaining damage. Similarly, once they get underway (or "sortie") ships must steer well clear of the highest winds and seas, to avoid personnel injuries and damage and ensure their stability limits are not exceeded. Storms of little consequence to the general public - those that remain well out at sea - are still of great concern to the Navy. Because of the need to sortie ahead of tropical cyclones, the Navy must make decisions 3- to 5-days in advance of potentially dangerous weather. Sortie decisions are extraordinarily difficult to make because of their high cost and impact on personnel and operations. In making these decisions, Fleet commanders must strike a balance between the risk of staying in port versus the cost and potential for damage at sea. Additionally, naval exercises and ship transits are often placed at risk by multiple tropical cyclone events, which can make successful evasion extremely difficult. Forecasts are provided to the fleet commanders and their staffs by the nearest NAVMETOCCOM activity. Within CONUS and adjacent ocean areas, tropical cyclone forecasts in particular are closely coordinated with those of the National Weather Service. Overseas, local tropical cyclone warnings and forecasts are based on guidance provided by the Joint Typhoon Warning Center, Pearl Harbor, Hawaii.

ARMY TRANSFORMATION

Global changes to the strategic environment dictate that the Army significantly alters the way it conducts business (Figure 3-DOD-11). On 12 October 1999, the Secretary of the Army and the Chief of Staff of the Army articulated a Vision designed to posture the Army so that it can better meet the demands of the 21st Century: "Soldiers on Point for the Nation…Persuasive in Peace, Invincible in War." The requirement to transform the Army is based upon emerging security challenges in the 21st Century as well as the requirement to respond more rapidly across the full spectrum of operations. In support of the National Security Strategy (NSS), the strategic significance of land forces lie in their ability to not only fight and win our Nation's wars, but also to provide options to shape the global environment to the future benefit of the United States and its allies. To this end, the Army developed a strategy and plan to guide this transformation.

Figure 3-DOD-11. The United States Army Strategic Environment.

The Army Vision is about People, Readiness and Transformation. People are the centerpiece of our formations; leadership is our stock in trade. It is imperative that we continue to take care of our quality soldiers, civilians, veterans and their families as we transform our Army. Readiness remains, as it has always been, our top priority. We have a non-negotiable contract with the American people - to fight and win the Nation's wars. We must ensure that at all times, the Army can meet demands of the National Military Strategy and requirements specified in the Joint Strategic Capabilities Plan (JSCP). Finally, the Army must transform, to become more strategically responsive and dominant at every point on the spectrum of operations.

The vision represents goals for the Army, while Transformation and its accompanying Transformation Campaign Plan (TCP) are vehicles for becoming more strategically responsive and dominant. Achieving the vision requires a complete transformation of the entire Army.

Transformation consists of three major objectives: Initial Force, Interim Force and Objective Force, with three corresponding phases (Figure 3-DOD-12). The first phase of Army Transformation has already begun. During this phase, the Army is fielding an Initial Force of two Brigade Combat Teams at Fort Lewis, Washington. During FY 2000-01, these two units will establish and validate an organizational and operational model for Interim Brigade Combat Teams. To bridge the gap between the capabilities of today's force and the Objective Force, it is necessary to field an Interim Force of six to eight brigades, employing the Interim Armored Vehicles (IAVs) and currently available off-the-shelf equipment. These Interim Brigade Combat Teams (IBCTs) will be the vanguard of the future Objective Force - they will have full spectrum capability and be available for apportionment to the warfighting CINCs. These Interim Brigades will also have the capability to deploy anywhere in the world in 96 hours. The Army envisions fielding the first units of the Objective Force in eight to ten years. This force will not only retain the capability to deploy a combat-capable brigade anywhere in the world in 96 hours, but also a division in 120 hours and five divisions in 30 days. The Objective Force will provide the National Command Authority (NCA) with an increased number of options for regional engagement, crisis response and sustained land force operations. The Objective Force is designed around a Future Combat System (FCS) that will incorporate state of the art technologies and capabilities into a multi-mission combat system. The Army has significantly increased spending in Science and Technology in order to develop the operational capabilities of the FCS and the overall force. Throughout the transformation, readiness remains our top priority - the Legacy Force provides this capability. The Army must fulfill its non-negotiable contract with the American people-to fight and win the Nation's wars. Therefore, the Army must sustain and recapitalize its Legacy Force to guarantee mainte-

nance of critical warfighting readiness. To accomplish this, the Army will recapitalize selected legacy formations, in its Active and Reserve Components, to enhance key armored and aviation systems, as well as enhance light force lethality and survivability.

These changes to the Army structure dictate changes in both weather support requirements and the way weather is provided to the new Brigade Combat Teams. Weather teams will be smaller in size and will depend more heavily on "reach back" capabilities to obtain meteorological data. The United States Air Force (USAF) is working with the Army to optimize the type and level of weather support that will be provided to the new brigades, while still maintaining appropriate support to the legacy force during transformation.

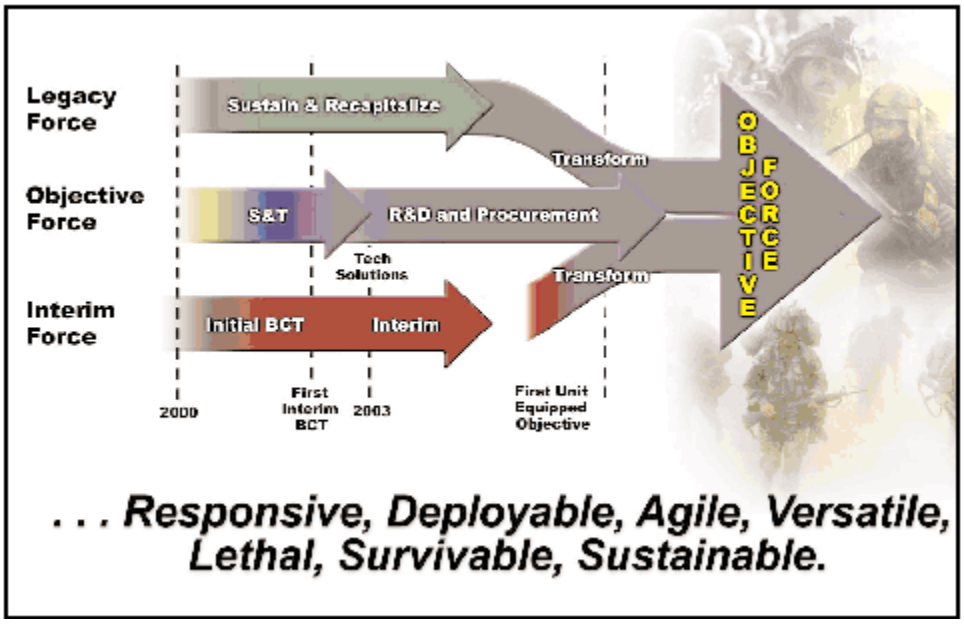


Figure 3-DOD-12. United States Army Transformation.

ARMY OPERATIONAL AND MISSION SUPPORT

United States Army weather support is a mix of Army and USAF personnel and equipment under Law and according to Army-Air Force (AF) agreement. Army Regulation (AR) 115-10/AF Joint Instruction (AFJI) 15-157, *Weather Support for the United States Army*, 30 June 1996 describes the Service responsibilities and those of Major Army Commands (MACOMs) within the Army providing weather support. The United States Army provides direct weather support to two Army missions: upper air observations for Field Artillery fire support, and limited surface weather observations to support Army weapon systems forward of Division tactical operations centers (Figure 3-DOD-13). AF Major Commands (MAJCOMs) provide operational weather services to warfighting MACOMs in combat, contingencies, and peacetime training. United States Army Forces Command (FORSCOM), United States Army Europe (USAREUR), United States Army Pacific (USARPAC), United States Army Special Operations Command (USASOC), Eighth United States Army (EUSA), and United States Army Training and Doctrine Command (TRADOC) have AF Weather personnel providing daily installation and tactical weather support. Army Artillery Meteorological (ARTYMET) crews provide direct upper air observation support to artillery units in the same MACOMs. During peacetime training and activation, the Air National Guard (ANG) provides AF operational weather support to the Army Reserve and Army National Guard (ARNG), collectively designated the Reserve Component (RC). In addition, during exercises and contingencies, the ANG may augment the active Army Combat Weather Teams (CWTs).

The Army also provides the operational weather support to Army Research Development, Test and Evaluation (RDTE) ranges, centers, and other research facilities using the Developmental Test Command's (DTC) Meteorological Teams (MET Teams) and United States Army Space and Missile Defense Command (SMDC) contractors. DTC operational support is described under Army Test and Evaluation Command. SMDC provides weather support to Kwajalein Missile Range (KMR) through a Meteorological Environmental Test Support contractor.

The Army provides the tactical field and communications equipment to USAF CWTs for tactical operations. The Integrated Meteorological System (IMETS) is an automated mobile weather support and communications system. The Project Director (PD) for IMETS is under the direction of Program Manager, Intelligence Fusion. The Communications and Electronics Command (CECOM) and Army Research Laboratory (ARL) provide fielding and technical support to PD, IMETS and to Field Artillery meteorology programs.

ARTYMET crews are assigned to Artillery units at Division level, to Field Artillery Brigades, and to Separate Brigades with a direct support Artillery Battalion. Army soldiers regularly take tactical upper air observations to support Field Artillery units during tactical training exercises, at permanent Army Artillery Ranges, or during the full range of combat missions. ARTYMET crews also take limited surface observations at tactical locations on an "as needed" basis to support artillery operational requirements.

ARTYMET Crews in the Active Component (AC) and RC sections currently use the Meteorological Measuring Set (MMS), AN/TMQ-41, to take upper air observations during tactical operations. It is a mobile, upper air sounding system mounted on a High Mobility Multi-purpose Wheeled Vehicle (HMMWV). The MMS provides upper air data to the Field Artillery Tactical Data System for use in adjusting artillery fire, to USAF CWTs, and to the Chemical Officer for use in smoke and in Nuclear, Biological and Chemical (NBC) defense operations. The CECOM section provides a complete description of MMS. The United States Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, develops the requirement documents and is the combat and training developer for meteorological equipment used for Field Artillery support.

The Army provides supplemental, limited surface observations when required in tactical situations to support Army operations. When directed by the Intelligence Officer (S2), Intelligence personnel in the forward combat areas take these observations.

Headquarters, Department of the Army, Office of the Deputy Chief of Staff for Intelligence (ODCSINT) is responsible for Army weather support policy. The Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS) is responsible for validating and prioritizing weather support requirements and programs to meet Army requirements. The Army Staff also has a full-time active duty User Liaison assigned to the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office and an Intelligence Officer assigned to the AFW Agency (AFWA) at Offutt AFB, Nebraska.

Army Operational Support provided by the Air Force

Under AR 115-10/AFJI 15-157, the AF is responsible for providing the Army with the necessary manpower and unique tactical and fixed weather equipment to meet Army tactical and garrison active component (AC)/RC support requirements. Army support manpower requirements are sourced from AF active, reserve, and ANG weather units. While direct support of the Field Artillery remains an Army responsibility and is supported by Army ARTYMET teams, AF CWTs provide supplemental information to artillery crews in contingencies for areas beyond direct ARTYMET observation capabilities. The AF assigns AF weather personnel to the warfighting MACOMs at theater, corps, division, armored cavalry regiments, aviation brigades, separate brigades, and special forces groups/ranger regiments to provide direct, on site weather support. AF weather squadrons and flights provide garrison and tactical weather warning, observing, forecasting, special support, and staff weather officer (SWO) services to Combat, Combat Support, and Combat Service Support units throughout the peacetime/war continuum. Peacetime garrison activities include supporting flying operations at Army Airfields and severe weather watch, warning, and advisory services for aircraft and post resource protection. The AF is responsible for installation, operation, and maintenance of standard AF meteorological and observing equipment at Army Airfield Weather Stations. Tactically, the Army is responsible for vehicles, tactical communications, and weather effects criteria. The Army Integrated Meteorological System (IMETS) is fielded for these purposes and is operated by AF CWTs. The Army also maintains IMETS hardware and software, with the AF maintaining AF software that performs meteorological functions within IMETS. IMETS uses AF meteorological software, but IMETS is built on an Army vehicle, uses Army tactical communications and Army weather effects software. The Army provides other tactical equipment to AF CWTs through an Army Table of Organizations and Equipment (TOE).

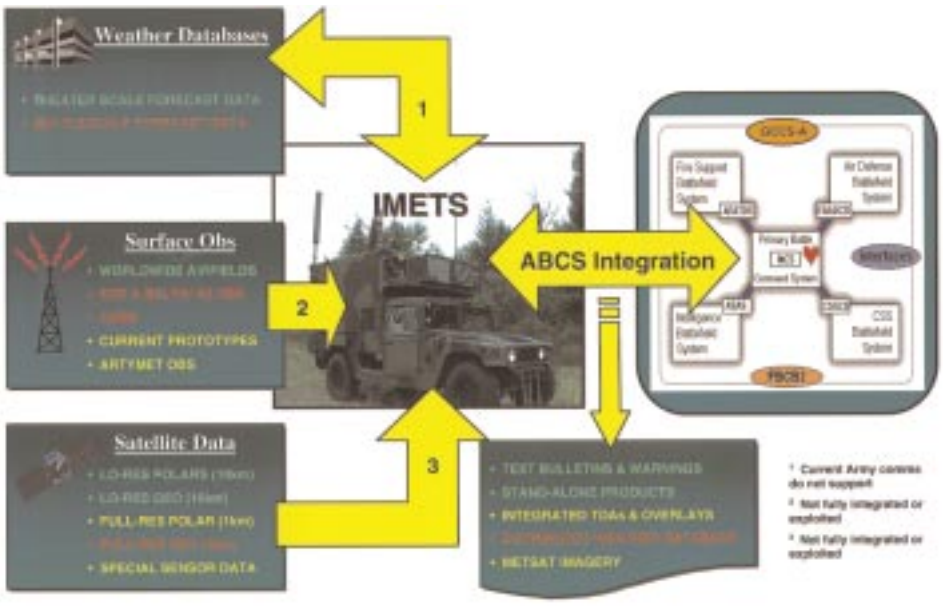


Figure 3-DOD-13. Army Weather Support Architecture.

Eighth United States Army Support

Eighth United States Army (EUSA) requires, and uses, Army resources to conduct two major meteorological services in direct support of Army operations: collecting and disseminating upper air observations for artillery support, and collecting and disseminating limited surface weather observations to support all tactical units and operations.

Two artillery meteorological (ARTYMET) crews with the Second Infantry Division use AN/TMQ-41 MMS to collect upper air observations for direct use by field artillery units. ARTYMET crews also collect upper air observations for training; these observations are available to the 607th Weather Squadron (607 WS) upon request.

Additionally, under the Forward Area Limited Observing Program (FALOP), Army personnel use tactical weather kits to collect limited weather observations in data sparse, forward areas. Observations are typically collected by intelligence personnel at brigade and battalion tactical operations centers (TOC) during contingencies or exercises and, in turn, are disseminated to and through USAF weather teams supporting Army air, ground, or special operations. These observations are used by forecasters at the 607 WS Theater Forecast Unit (TFU) to accurately predict mission limiting weather in the demilitarized zone (DMZ).

The USAF will use new automated COTS observing systems at eight locations in the area of the DMZ. Observations from these systems will be transmitted via phone lines to pilots, as well as to forecasters back in the 607 WS TFU. They will also be incorporated into the global weather database to improve short term forecasting in the northern ROK. There are plans to buy more automated COTS sensors in FY 2002, for use along the DMZ and in the northern ROK.

USAF weather personnel assigned to the 607 WS provide fixed and tactical weather support to EUSA units and installations. 607 WS provides garrison and tactical weather warning, observing, forecast, special support, and staff weather officer (SWO) services during contingency, exercise, or armistice operations. 607 WS units provide direct, on-site support at eight EUSA installations and at deployed locations. Support is focused on air, ground, special operations, and other combat and combat support missions. The 607 WS TFU took over forecasting responsibilities for the eight EUSA locations in FY 2000, and is responsible for terminal aerodrome forecasts, along with weather advisories and forecasts for these locations. The EUSA CWTs are primarily responsible for providing their customers with observations and tailored support. 607WS provides 97 trained weather personnel and required fixed and tactical weather sensing, data processing, and communications equipment. EUSA provides supporting USAF units needed tactical vehicles, MTOE and CTA equipment, and operating funds (for expendables, maintenance, etc.).

United States Army In Europe And Seventh Army

United States Army Europe (USAREUR) and 7th Army require and use Army resources to conduct meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating limited surface weather observations to support all tactical units and operations.

7th Weather Squadron (7 WS) provides USAREUR/7th Army in-garrison and tactical weather intelligence and support. This includes observing services for in-garrison operations, contingency and exercise operations, staff weather officer (SWO) services, and specialized support. The United States Air Forces in Europe (USAFE) Operational Weather Squadron (OWS) at Sembach AB, Germany, provides operational-level forecast products for the European Command Area of Responsibility, to include all USAREUR units (Figure 3-DOD-14). Combat weather teams located at V Corps and its aviation assets, 1st Infantry Division and its aviation brigade, 1st Armored Division and it aviation brigade, evaluate and tailor these forecast products to produce mission execution forecasts.

The mission of 7 WS and its ten detachments is to provide weather operations packages to conform to the Army's Transformation initiative. 7 WS will match the deploying weather force structure to the mission that USAREUR is called upon to execute. 7 WS will utilize "reachback" capabilities to the maximum extent possible to minimize the deployed footprint without compromising weather operations.

The Automated Meteorological Information System (AMIS) is the primary in-garrison weather equipment for receiving graphics and alphanumeric data. Data is received via VSAT and hard-wire circuits. The New Tactical Forecast System (NTFS) is the primary equipment used for deployed locations with data received via TV-SAT, NIPRNET and SIPRNET. Units also use the NATO Automated Meteorological Information System (NAMIS) to receive NATO generated

Figure 3-DOD-14. United States Army Soldiers on partol in Bosnia.

weather products. NAMIS software is hosted on a laptop and receives data via VSAT. Satellite imagery (METEOSAT and DMSP) is received via the Small Tactical Terminal (STT). Five Integrated Meteorological Systems (IMETS) have been fielded within USAREUR, with two more programmed for FY 2002. Five Portable Automated Observing Systems (PASOS) and Portable Weather Radar are deployed to Task Force Falcon (TFF), Kosovo, with an additional PASOS unit currently being installed.

USAREUR provides supporting USAF weather teams with tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment and operating funds (expendables, maintenance, etc.). Four artillery meteorological (ARTYMET) sections collect upper air observations for direct use by field artillery units. The Forward Area Limited Observing Program (FALOP) consists of Army personnel taking limited observations at forward areas in the battlespace.

United States Army Special Operations Command (USASOC)

Weather support to USASOC consists of forecasts and observations, climatological studies and course of action recommendations to aid commanders in improving efficiency, effectiveness, and safety of operations for USASOC units. USASOC personnel provide limited scope meteorological observations in direct support of Army operations using tactical weather kits to collect limited weather data in data sparse permissive and non-permissive environments. Observations are typically collected by Army Special Operations Forces at the team level and are passed to operating bases for use by Army commanders and staff, as well as AF Special Operations Command (AFSOC) and ANG weather personnel. AFSOC and ANG weather personnel supporting USASOC are assigned to the 10th Combat Weather Squadron (CWS), OL-A, 320 Special Tactics Squadron (STS), OL-A, 321 STS and the 107th, 146th, and 181st ANG Combat Weather Flights (CWF's). These weather units provide garrison and tactical support to USASOC units including the 75th Ranger Regiment and subordinate battalions, the 160th Special Operations Aviation Regiment, seven Special Forces Groups and subordinate battalions and two Psychological Operations Groups. Support provided includes climatological information, mission forecasts, command decision forecasts, aviation forecasts and observations, drop zone forecasts and observations, special reconnaissance, and Foreign Internal Defense/Unconven-tional Warfare. The 10 CWS also provides staff support to USASOC, the United States Army Special Forces Command (Airborne), and the United States Army John F. Kennedy Special Warfare Center and School. USASOC provides supporting AFSOC and ANG units with required facilities, equipment, and operating funds (for expendables, maintenance, etc.).

United States Army Pacific (USARPAC)

USARPAC uses Army resources to conduct meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating surface weather observations to support tactical units and operations.

USARPAC provides supporting USAF units with tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment and operations and maintenance funds.

The IMETS and New Tactical Forecast System (NTFS) have been fielded within USARPAC as the primary meteorological equipment for deployed operations. The IMETS and NTFS reachback for data via Army provided NIPRNET and SIPRNET conduits. Deployed weather teams also use the Small Tactical Terminal (STT) for direct reception of weather satellite imagery.

In FY 2001 the 17th Operational Weather Squadron (17 OWS) was activated, as part of ongoing reengineering and realigning. The 17 OWS provides CWTs within its area of responsibility with garrison and tactical weather warnings, forecasts, special support, and Staff Weather Officer (SWO) services during contingencies and humanitarian operations. Additional CWTs assigned to United States Army Japan (USARJ), 25th ID and 172nd SIB provide direct, on-site support at five USARPAC installations. The CWTs also deploy with their customers providing tailored battlefield observations and forecasts. Weather reengineering will reduce the requirement for forward deployed weather personnel, and instead leverage IMETS and other recently fielded technology. The 17 OWS, through reachback, will provide regional weather support, allowing the forward-deployed forces to focus on specific area and target forecasts.

United States Army Forces Command (FORSCOM)

Weather support to the United States Army Forces Command (FORSCOM) is diverse and demanding. FORSCOM is the Army's largest major command and requires and uses Army resources to conduct meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating limited surface weather observations to support all tactical units and operations. FORSCOM consists of more than 760,000 Active Army (AA), United States Army Reserve and ARNG soldiers. These soldiers account for around 85 percent of the Army's combat power. FORSCOM trains, mobilizes, deploys, and sustains combat ready forces capable of responding rapidly to crises worldwide. The AA of FORSCOM

has nearly 200,000 soldiers. Third United States Army is the Army component of United States Central Command (USCENTCOM), the Joint command responsible for Southwest Asia (SWA) and the Horn of Africa. FORSCOM also commands two Army Corps: III Corps at Fort Hood, Texas; and XVIII Airborne Corps at Fort Bragg, North Carolina. Together they include six divisions, two armored cavalry regiments, five separate brigades, and a range of other corps combat, combat support and combat service support units. The two Continental United States Armies (CONUSAs), First United States Army and Fifth United States Army, are responsible for training, mobilization and deployment support to Reserve Component units in FORSCOM.

A major subordinate command of FORSCOM, the United States Army Reserve Command (USARC) commands all United States Army Reserve units in the continental United States, except those assigned to Special Operations Command. FORSCOM's Army Reserve strength stands at about 196,000 soldiers. USARC units are part of the Federal force and make their primary contribution to FORSCOM combat power in combat support and combat service support specialties such as medical, civil affairs, transportation, maintenance and supply.

The ARNG provides FORSCOM a balanced force of eight National Guard combat divisions, 15 enhanced separate brigades, and extensive combat support and combat service support units. The current FORSCOM ARNG strength is approximately 367,000 soldiers.

United States Army Signal Command also falls under control of FORSCOM and provides all Echelon Above Corps (EAC) tactical, power projection, and strategic signal support to warfighting unified commanders, as well as Army component commanders, in both war and peace.

Weather support to FORSCOM's AA units comes from dedicated AF weather teams aligned under three Air Support Operations Groups (ASOGs): 1st ASOG at Fort Lewis, Washington; 3rd ASOG at Fort Hood, Texas; and 18th ASOG at Pope AFB, North Carolina. A weather squadron for each ASOG makes up the Corps combat weather team (CWT). Each Army division has their own dedicated CWT. These CWTs are aligned under an Air Support Operations Squadron (ASOS) or one of the weather squadrons, at their respective installations. Corps and division CWTs are authorized enough personnel and equipment to support a variety of missions at the various Army echelons. Weather support at each Army echelon is provided according to Army Field Manual 34-81/AF Joint Pamphlet 15-127, Weather Support for Army Tactical Operations. Currently, there are nearly 350 AF weather authorizations supporting various echelons across FORSCOM. These AFW personnel provide garrison and tactical weather warning, observing, forecast, special support, and staff weather officer (SWO) services during contingency, exercise, or armistice operations.

FORSCOM weather units provide direct, on-site support at 11 major installations, including the National Training Center at Fort Irwin, California, and the Joint Readiness Training Center at Fort Polk, Louisiana and at deployed locations. Support is focused on air, ground, special operations, and other combat and combat support missions.

FORSCOM provides supporting USAF units with a Modified Table of Organization and Equipment (MTOE) and operating funds (expendables, maintenance, etc.). Eleven artillery meteorological (ARTYMET) sections collect upper air observations for direct use by field artillery units. The Forward Area Limited Observing Program (FALOP) consists of Army personnel taking limited observations at forward areas in the battlespace.

The Automated Meteorological Information System (AMIS) is the primary in-garrison weather equipment for receiving graphics and alphanumeric data. Data is received via VSAT and hard-wire circuits. The New Tactical Forecast System (NTFS) is the primary equipment used for deployed locations with data received via NIPRNET and SIPRNET. Satellite imagery (METEOSAT and DMSP) is received via the Small Tactical Terminal (STT). Nineteen IMETS have been fielded within FORSCOM. Two Automated Surface Observing Systems (ASOS) with one located Yakima Training Center and the other a Camp Doha, Kuwait.

Training and Doctrine Command (TRADOC) Programs

HQ TRADOC is responsible for development and management of training programs, writing Army and Joint weather support doctrine (concepts and field manuals), and establishing the weather requirements documents for Army tactical weather support equipment. Headquarters, TRADOC is the approval authority for Army-AF weather doctrine, Army weather hardware requirements, and weather support policy. A key mission area for the next few years will be to coordinate Army weather support requirements during AFW Reengineering and Army Transformation. Deployed weather support will improve significantly with the digitization of these experimental Army units. Customized battlefield weather "visualizations" transmitted via the Integrated Meteorological System (IMETS) will take the place of the stand-up weather briefings of the past. The results of the Advanced Warfighting Experiments (AWEs) will show us new tactics, techniques, and procedures for the exploitation of weather during military operations. Identified software enhancements will

transition to the appropriate materiel developer for further integration. Finally, these experiments provide an opportunity to educate Army leaders and their staffs on the effects of weather on the battlefields of the future.

Weather Support Process

TRADOC schools submit requirements for weather support to HQ TRADOC for approval. Upon concurrence, HQ TRADOC normally states requirements for USAF support to HQ, Air Staff - Director of Weather, for solution/implementation. Requirements for Army-provided communications or tactical equipment are submitted through ODCSOPS to prioritize and program resources.

The United States Army Intelligence Center and Fort Huachuca (USAIC&FH) is the Army's functional proponent for tactical weather support. The Weather Support Team (WST) advises the Commanding General of USAIC&FH, ARL, and AFW on Army-wide weather support requirements and known deficiencies. They frame requirements to meet both active and reserve force needs. They assist in training development for AFW personnel supporting the Army (i.e., the Staff Weather Officer Army Indoctrination Course), as well as training Army leaders to leverage weather intelligence on the battlefield (Figure 3-DOD-15). With dwindling resources and personnel reductions, the team has sought solutions that are compatible with AFW Reengineering plans and that maintain quality weather support to the Army warfighter. The USAIC&FH WST currently consists of an AF Staff Weather Officer, one senior AF Noncommissioned Officer, plus other USAIC&FH intelligence analysts and combat developers on a task-organized basis.

The Staff Weather Officer at the United States Army Combined Arms Center facilitates modifications to the Tables of Organization and Equipment for Army CWTs, and through the TRADOC System Manager for Army Battle Command System and Battle Command Battle Lab-Leavenworth, provides environmental data for the Command, Control, Communications, Computer and Information (C^4I) network.

The Schools and Battle Laboratories

The United States Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, is the proponent for upper air meteorological support to the Army. Artillery meteorological crews, Active and Reserve, currently use the AN/TMQ-50 to measure surface weather parameters, and the MMS, AN/TMQ-41 to take upper air observations. The MMS provides weather data to the Field Artillery Tactical Data System for ballistic calculations; to USAF CWTs for weather forecasting; and to the Chemical Officer for obscurant deployment, and Nuclear, Biological, Chemical (NBC) defense operations.

The Engineer School (USAES), Fort Leonard Wood, Missouri, coordinates weather support requirements for Terrain Analysis and Topographic Engineering. USAES develops methods of measuring and forecasting state of the ground for trafficability assessments, using input weather data fields. Their mission also includes identifying, and documenting requirements to interface meteorological and engineer battlefield systems. Due to force cuts, USAES no longer has a full time civilian meteorologist in the Terrain Visualization Center, DCD. (Operating Location B, 3rd Weather Squadron, USAF, provides weather observation services at Forney Army Airfield, Fort Leonard Wood, Missouri. OL-B is included in this report only to the extent that Fort Leonard Wood provides funding for its expendables and overhead.)

In 1999, the Army Military Police and Chemical Schools moved to Fort Leonard Wood. Neither currently employ staff meteorologists.

The Aviation Center at Fort Rucker incorporates weather instruction and procedures into rotary-wing training programs in their mission areas. The Center has requirements for weather observations and USAF forecast support at Cairns Army Airfield, Troy Municipal Airport (MAP), Alabama, and Andalusia MAP, Alabama. Additionally, Fort Rucker operates observing and communications equipment to relay weather intelligence and resource protection advisories to numerous Army remote training sites.

Army National Guard Artillery

The ARNG has 48 Meteorological

Figure 3-DOD-15. Ft. Drum Weather Team at the Joint Readiness Training Center.

Sections assigned to artillery units at Division level, Field Artillery Brigades, and in Separate Brigades. The ARTYMET sections provide upper air observations at least 39 training days each year supporting artillery live fire during Annual Training and monthly Inactive Duty Training. The ARTYMET sections support an average of 20 live fire training days and annually expend in excess of 100 balloons per section. The ARNG is in the process of modernizing to the MMS, AN/TMQ-41A. Active component fielding of Profiler will facilitate continued modernization through the cascade of MMS to the ARNG.

Army Corps of Engineers Civil Operational Activities

The Corps of Engineers (COE) uses a network of about 8,810 land-based gauges. About 55 percent of the sites collect meteorological data, 35 percent a combination of hydrologic and meteorological data, and 10 percent hydrologic or water quality data. The Corps funds or partially funds 61 percent (4,500) of all the gauges it used. Meteorological gauges commonly measure precipitation, temperature. Meteorological data represents only about ten percent of the COE's gauging program funding. Most gauging stations include hydrologic measurements for surface water runoff, water quality and sediment. All data is used in the regulation of COE dams and other water projects used for flood control, navigation, hydroelectric power, irrigation, water supply, water quality, and recreation. The COE transfers funds to NOAA/National Weather Service (NWS) to collect and maintain precipitation information from 600 of meteorological sites. Similarly, COE transfers funds to the United States Geological Survey (USGS) to maintain precipitation data collection from 500 sites, while the COE maintains the rest. Eight-two percent of all Corps sites provide real-time via satellite microwaves meter-bursts, landlines or radio. Data from all COE networks are available and used by other federal, state and local agencies, and are extensively used by NWS and USGS to support their programs.

United States Army Space and Missile Defense Command (USASMDC)

Army Space Command (ARSPACE), a SMDC component, provides operational space weather support on a limited basis to Army units through it's Army Space Support Teams (ARSST) as well as Space Operations Officers (FA40). ARSST teams and FA 40s' provide space weather support to the warfighter through an Army - AF agreement where ARSPACE will provide space weather support until an appropriate number of AFW personnel are trained in space weather and assume the mission. Space weather support is provided to Army warfighters as part of ARSPACE's effort to improved overall space support and situational awareness. Potential space weather effects including disruptions of over the horizon communications, radar interference, space environment induced satellite service disruptions, high flyer radiation hazards and hazard warnings to civil power grids resulting from geomagnetic activity.

Related projects include the annually updated Space Weather Smart Book that is intended to improve the ARSPACE staff, ARSST teams and FA 40s understanding of space weather fundamentals. In addition, ARSPACE is developing a Space Intelligence Preparation of the Battlefield (SPACE-IPB) visualization tool that will include a visual depiction of scintillation (disturbed ionosphere) conditions over a given operational area.

ARSPACE provides space weather support through a .5 staff year contract valued at $53,000. There has been no change in funding levels between FY 2001 and FY 2002.

The High Energy Laser Systems Test Facility (HELSTF), a subcommand of USASMDC located on White Sands Missile Range, is designated as the DOD National Test Range for high energy laser test and evaluation. In addition to laser systems test and evaluation, extensive use has been made of on-site laser systems to perform damage and vulnerability testing on laser-hardened materials, missile and aircraft components, and assorted battlefield equipment. The atmospheric sciences/meteorological mission is to support HELSTF activities by providing atmospheric propagation and meteorological measurements, planning, and analysis as required. These capabilities also support the safe storage, handling and use of the toxic laser fuels.

United States Army Kwajalein Atoll (USAKA) is a subcommand of USASMDC, which provides operational support to the test facilities at the Kwajalein Missile Range (KMR). The KMR meteorological services support contractor performs meteorological functions in support of missile operations and for synoptic purposes, including surface, upper air, and meteorological satellite observations, and the preparation of daily aviation, marine and special weather observations for the range.

WEATHER SUPPORT FOR RESEARCH, DEVELOPMENT, TEST, AND EVALUATION (RDTE)

Under Army-AF agreement, the Army has responsibility for weather support for research, development, test, and evaluation (RDTE) to support Army ground combat missions as specified in AR 115-10/AFJI 15-157. The COE and the Army Materiel Command (AMC) are the major contributors to weather research. The Medical Research and Materiel Command does research related to soldiers performance in the range of weather conditions expected to be encountered in all theaters of operations.

Corps of Engineers

The Corps of Engineers (COE)

Engineer Research and Development Center (ERDC) performs military engineering and civil works research through its seven laboratories at 4 geographic sites (Champaign, Illinois; Arlington, Virginia; Hanover, New Hampshire; and Vicksburg, Mississippi). The ERDC manages the Military Engineering research program addressing a wide range of topographic and combat engineering future operational capabilities (FOCs). The ERDC also is responsible for reviewing all emerging Army systems for environmental effects, as stated in AR 70-1. Many of the tactical decision aids (TDAs) developed within the military engineering program interpret the impact of weather and terrain conditions on Army systems and operations. They are based on weather and terrain limitations, known as critical values. Critical values define system limitations and are used by decision-makers to take advantage over opposing forces. Technology advancements are transitioned to terrain and weather systems such as the IMETS, the Digital Topographic Support System (DTSS), the Army Tactical Command and Control System (ATCCS). The COE Topographic Engineering Center (TEC), Arlington, Virginia, provides basic and applied environmental support to Army R&D programs and coordinates the development of TDAs relating to environmental effects on combat systems, operations, and personnel. This support includes the development of: (1) environmental effects databases and models that are relevant to military plans, operations and the acquisition communities; (2) models and techniques to assist in the generation of proxy environmental information (climate and terrain) for data sparse areas and the integration of models to enable the spreading of this information spatially over map backgrounds; and (3) integrated software modules that are designed to be exploited in the synthetic environment arena and techniques to portray natural and induced battlefield environments, thus enhancing computerized battle simulations. TEC also contributes to the development of policies and procedures for the consideration of realistic natural environmental conditions for application in the materiel acquisition process. The Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire, conducts research in sensor signal interaction with snow, ice, and frozen soil, icing accretion on surfaces and structures, deicing technologies, and cold regions surface-air boundary process. CRREL develops databases and models predicting infrared and millimeter wave (MMW) weapon system performance, and the capability of technology to enhance military operations in cold environments. Other specific programs include weather effects on environmental research for military training lands, helicopter pre-flight deicing and airborne icing avoidance, remote sensing for predicting snow coverage and snow-water equivalence for snow melt runoff, and modeling winter effects for input into Army operational and training models and simulations.

Army Matériel Command (AMC)

The Army Matériel Command (AMC) is responsible for the design, development, test, and evaluation of equipment to satisfy requirements for meteorological support equipment. AMC provides climatological and meteorological support to RDTE projects involving electro-optics and obscurants. It is also responsible for determining weather effects critical threshold values and environmental sensitivities of battlefield systems. AMC has several subcommands and elements carrying out weather research and development responsibilities.

The Army Research Laboratory (ARL) Battlefield Environment (BE) Division is the lead DOD agency for research and development in the portion of the atmosphere unique to the Army warfighter's battlespace--the planetary boundary layer. BE's mission is to provide the technology and tools (1) for the Warfighter to exploit weather on the battlefield, (2) for the Commander to avoid exposing the Soldier to environmental hazards, (3) for the Materiel Developer to minimize system weather impacts, supplying atmospheric effects information and (4) increase the battlefield situational awareness by accurately assessing environmental effects. The joint Army/AF "*Own The Weather*" initiative provides the knowledge of current and forecasted battlefield environmental conditions, along with their effects on systems, soldiers, operations, and tactics, to contribute to achieving the Army's decisive advantage over its opponents. Within the DOD, BE is the lead agency for multi-service R&D programs in transport and dispersion modeling, boundary layer meteorology over land, atmospheric effects on acoustic and electro-optic propagation, and mobile atmospheric profiling. In addition, BE contributes to tri-service goals in the areas of theater data fusion and predictions, boundary layer processes, and atmospheric effects. The BE program is driven by the Army's need for meteorological information at smaller scales than used by either the AF, Navy, or civilian community, and over data-sparse geographic regions. While the AF provides the Army with is basic tactical weather support, the Army provides technology to support such service-unique requirements, and Army systems, as well as distributing this weather intelligence information to the Army Battle Command Systems (ABCS) on the battlefield.

The Army has begun an active reprogramming to respond to the new AFW Re-Engineering initiatives, and will work to ensure the ongoing success of the Army weather intelligence technology. BE continues to develop and provide the software tools for the

Army's Integrated Meteorological System (IMETS), and works with the AFWA and Combat Weather Center to make IMETS an integral part of the total battlefield weather support mission.

The BE Division within the ARL Computational and Information Sciences Directorate, consists of four Branches, two each at the ARL primary side at Adelphi, Maryland, and the White Sand Missile Range, New Mexico. These four branches combine basic research programs focused in the areas of chemical/biological transport and dispersion theory, and in-depth understanding of the meteorological processes inherent in the planetary boundary layer, with an applied research development program focused on transitioning of products for Army tactical operations. BE opened an experimental site at Blossom Point, Maryland, in mid-1998, in a complex littoral region on the north shore of the Potomac River, and is able to conduct field experiments in electro-optic and acoustic propagation, as well as test weather modeling tools.

At the Adelphi Laboratory Center (ALC) in Maryland the two branches are (1) the Atmospheric Acoustics and Electro-Optics (A&EO) Propagation Branch and the (2) the Boundary Layer Meteorology and Aerosol Research Branch (BLM&AR). The A&EO Branch provides basic research in the modeling and simulation of environmental effects on acoustic and electro-optics propagation, and laboratory and field experimental research into environmental effects on acoustic and electro-optic propagation and the mitigation of those effects. The BLM&AR Branch conducts a research program in the micrometeorological processes and structure of the atmospheric boundary layer. This program focuses on the interaction of the land-air interface with wind fields, turbulence, and fluxes and on optical methods of detection of aerosols (primarily chemical-biological agents) and the modeling of their transport and dispersion in the tactical environment.

At the Weather Exploitation Branch, located at the White Sands Missile Range location, research and development efforts involve several areas. They address tactical weather data assimilation and distribution, to include exploitation of commercial and military satellite technology to move meteorological data to the battlefield Tactical Operations Centers and between echelons. They generate gridded meteorological databases to support C^4I systems, mission planning and rehearsal, and integrate weather forecast analysis tools to identify the location and timing of hazardous and significant weather at small scales in the boundary layer. They develop rule-based tactical decision aids for impacts of weather on military systems, platforms and operations. And, they integrate physics based weather effects models and meteorological satellite analysis algorithms with weather data visualization tools for improved mission planning and situation awareness. As part of the tactical weather product development, the branch also performs the following: configuration management and validation of new products; improvements through end-user feedback from Advanced Warfighting Experiments, TRADOC Concept Experimentation Programs, and integration at the Army's Central Technical Support Facility at Fort Hood; and delivery of software for integration into IMETS. The IMETS integration includes tactical weather overlays, databases of dynamic gridded weather parameters, weather effects decision aids, and weather data visualization tools, all of which can be executed in the field using Common Hardware/ Software and Common Operating Environments.

BE develops the weather application software for IMETS that is part of the Army's effort to Digitize the Battlefield and will provide weather capabilities in the Army's First Digitized Division (FDD) in FY 2000 and the First Digitized Corps in FY 2001. From FY 1997 to the present, BE has successfully used the Army's Task Force XXI Advanced Warfighting Experiments (AWE's) to evaluate and improve its delivered IMETS Block I and Block II software. In FY 1999 and FY 2000, the BE/IMETS tactical weather applications were being upgraded and delivered for integration to the other C^4I tactical systems operating under the Army Battle Command System, version 5.0 (ABCS 5.0). These IMETS applications incorporate significant changes in the sharing of data between Battlefield Functional Areas by exploiting client/server relationships and the IMETS Gridded Meteorological Database. The weather overlays are converted to use the Joint Mapping Tool Kit (JMTK) software for map overlays. And, the initial integration of AFW Re-engineering includes passing meteorological data and products from AF central hub sites to the Army battlefield TOC's using WMO data standards such as GRIB and BUFR. The weather impact rules and critical values for the BE-developed Integrated Weather Effects Decision Aid (IWEDA) have been assembled jointly across the services to provide a common rule-base for weather impact decision aids.

The Artillery Meteorology Branch, also located at the WSMR site, combines a research and development program that focuses on the means to measure, process, analyze, and predict atmospheric conditions in target areas for fire support and related Army activities. Technical expertise and support is provided directly to the PM NV/RSTA and PM TESA in the design and development of the Engineering Manufacturing Development (EMD) Profiler system. Research is being focused on

developing new algorithms for the retrieval of meteorological parameters and profiles that will lead to the ability to process meteorological data at rates approximating real-time. Research is also underway in enabling technologies that will permit the handling and transfer of large met data sets over the distributed, net centric force of the future.

The Army Research Office (ARO), Research Triangle Park, North Carolina, manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with understanding the dynamics and kinematics processes of the atmospheric boundary layer at scales of interest to the Army (millimeters to 10's of kilometers) through measurements, simulations, and theoretical considerations. The basic research program is conducted through the peer-reviewed, individual investigator program and occasional special initiatives. The focus of the research is on the atmospheric processes and effects of the atmospheric boundary layer where the Army operates. Objectives of the research are to develop, from first principles, the physical basis for understanding the boundary layer processes, thereby leading to better understanding of atmospheric effects on soldiers, materials, and weapon systems. The research examines dispersion of battlefield materials, the effects of heterogeneous terrain features on airflow, and the development of natural obscurations throughout the diurnal cycle. An essential element of the research is the development of instrumentation to measure the volumetric fields of wind velocity, temperature, and moisture of the boundary layer at turbulence time scales. Other areas of special funding are also managed. The Defense University Research and Instrumentation Program (DURIP) provides funds for instrumentation needed to support ongoing research activities. The Defense Experimental Program to Stimulate Competitive Research (EPSCoR) participation is a competition restricted to universities in certain states that compete for additional basic research funds. Also basic research under the Small Business Innovative Research Program (SBIR) is managed for selected topics. At the Army Research Office, funding for basic research remains relatively static. Increased funding will come if special program initiatives or requests are approved. The primary focus will be on analysis and understanding of data taken in a recent field study of the stable boundary layer.

The CECOM Logistic Readiness Center is the level II manager of the MMS program. It is supported by the Information and Intelligence Warfare Directorate and other internal organizations in developing and fielding weather support systems. CECOM also provides support to the Program Manager, Intelligence Fusion and Program Manager, Night Vision/ Reconnaissance, Surveillance, and Target Acquisition with technical management of weather programs. Current programs supported are the MMS, MMS-Profiler (MMS-P), and the Integrated Meteorological System (IMETS). A brief description of each of these programs shows CECOM's involvement.

Meteorological Measuring Set, AN/TMQ-41. The MMS is an upper air meteorological data collection, processing and dissemination system that provides data to the field artillery and target acquisition users. The system is a non-developmental item (NDI). All active Army units are equipped with the MMS. Additional systems to modernize the National Guard were begun in FY 1999 and will continue through FY 2002. In FY 2001, the Army bought an additional 14 systems. More systems are anticipated as being bought in FY 2002.

Meteorological Measuring Set-Profiler, AN/TMQ-52 System. The Meteorological Measurement Set-Profiler (MMS-P) is a major improvement over the MMS. The AN/TMQ-52 designed to support the new generation of artillery weapons. It will provide more frequent messages with validity over a larger battlespace than current equipment. The MMS-P uses the MM5 mesoscale meteorological model to assimilate data from a variety of sources to provide the best meteorological messages to the user in a timely fashion. The system receives data from ground-based sources, from radiosondes, and from satellite-based sources, such as boundary data from communications and polar orbiting meteorological satellites, through on-board satellite receiving capability. The data is used to affect the operation of the mesoscale meteorological model and for post-processing of the data so that all the required meteorological messages can be generated. Finally, an operator interface, in conjunction with the message generation and formatting software, facilitates communication between the MMS-P and all other systems that require interoperability with the MMS-P. Currently in development are four Engineering and Manufacturing Development (EMD) models. Development and testing will be accomplished during FY 2001 and FY 2002, with testing and a production decision scheduled for FY 2003.

Integrated Meteorological System, AN/TMQ-40B. The IMETS is the weather component of the Intelligence Electronic Warfare (IEW) sub-element of the Army Battle Command System (ABCS). The IMETS provides commanders at all echelons with an automated tactical weather system that receives, processes, and disseminates weather observations, forecasts, battlefield visualization, and weather effects decision aids to all Army Tactical Command and Control System (ATCCS) Battlefield Functional Areas

(BFAs). IMETS receives weather information from polar-orbiting civilian and defense meteorological satellites, civilian forecast centers, the AFW Agency, artillery meteorological sections and remote sensors. IMETS processes and collates forecasts, observations, and climatological data to produce timely and accurate weather products tailored to the specific warfighter's needs. The most significant weather and environmental support to warfighters are the automated tactical decision aids. These graphics display the impact of the weather on current or planned operations for both friendly and enemy forces. The warfighter can thus more effectively employ his forces and weapons systems to achieve success in battle.

FY 2002 efforts will focus on four main areas. The Army will field one AN/TMQ-40C vehicle mounted configuration and complete the upgrade of twenty fielded IMETS from AN/TMQ-40A's to AN/TMQ-40B. The Army will also hand-receipt a second IMETS Light to the IBCT and will conduct an IMETS Light combined developmental and operational test in order to achieve a Milestone III decision for fielding this configuration.

Army Test and Evaluation Command (ATEC)

The Developmental Test Command (DTC), a subordinate command of United States Army Test and Evaluation Command (ATEC), is responsible for providing operational meteorological support to eight Army ranges and test sites. Under responsibilities established in AR 115-10/ AFJI 15-157, the DTC meteorological units provide meteorological data collection and analysis, consultation, and weather forecast and warning services to support Army and other DOD research, development, test and evaluation (RDT&E) activities at the eight Army installations. Funding for the Army RDT&E Meteorology Program under Program Element 665702 has stabilized after several years of decline and is sufficient to maintain the basic meteorological support infrastructure at Army RDT&E ranges and sites. However, instrumentation needed to support unique or test-specific requirements generally must be funded by test sponsors.

The Army RDT&E Meteorology Program has entered into a multi-year working relationship with the National Center for Atmospheric Research (NCAR) to enhance "range scale" (mesoscale to microscale) forecast and analysis technology. The principal product of this relationship is the Four-Dimensional Weather (4DWX) System, which consists of a central data archival/retrieval system for all range and external meteorological and model data, a high-resolution mesoscale meteorological model, and a variety of user-configurable displays. The MM5 mesoscale model is used operationally in both predictive and analysis modes to provide detailed information about the past, current, and forecast structure of the atmosphere over the Army's test ranges. Output from both MM5 forecasts and analyses is used as meteorological input to atmospheric dispersion, noise propagation, ballistic trajectory, and other range applications models to simulate many tests and their associated impacts. The 4DWX system contributes to improved test planning and conduct, selection of more representative locations for test sensors, inclusion of realistic atmospheric effects in virtual testing, and forensic analyses of meteorological effects on test results.

The Chief of the Meteorology and Obscurants Division at Dugway Proving Ground's West Desert Test Center serves as the Program Manager for Meteorological Support to Army RDT&E. Under Program Element 0605384, the Division's Modeling and Assessment Branch also provides the following specialized services: (1) atmospheric model verification and validation, including algorithm evaluation and the generation of validation data sets; (2) chemical/biological threat analysis, detection, and decontamination tests and studies for the Joint Contact Point Project (DO49); and (3) prototype development of virtual proving ground meteorological support. Division employees also serve on various national and international committees addressing issues related to meteorological measurements, atmospheric dispersion modeling, and chemical/biological hazard assessment.

Army Medical Research and Matériel Command

The United States Army Research Institute of Environmental Medicine (USARIEM) conducts basic and applied research on the effects of heat, cold, high terrestrial altitude, and nutritional status on the health and performance of individual soldiers and combat crews operating Army systems.

Applied research in thermal physiology and biophysical modeling are directed toward improving soldier performance and minimizing health risks in climatic extremes. The sensitivity of the soldier to local weather parameters (primarily ambient temperature, dew point, wind speed, and solar radiation) defines an operational envelope for unimpaired human performance. The overall goals of USARIEM's weather-related research programs are to develop methods to effectively monitor and, where possible, extend the operational envelope for both training and operational scenarios.

Weather-related research efforts include the development and validation of automated methods to integrate thermal strain prediction models with real-time weather information resources relevant to dismounted infantry operations. Temporal and spatial scales of interest are meters to kilometers and minutes to several days.

The Operational Medicine Environmental Grid Applications (OMEGA)

project is a software development effort intended to provide an integrated research platform for the evaluation of predictive modeling strategies for warfighters. It enables the integration of digital terrain data and real-time weather information with candidate physiologically-based environmental injury risk and performance prediction models. This test-bed system has a field of view of up to 200x200 km and uses a color-coded map overlay display format. The web-enabled client-server architecture and archiving resources of OMEGA are intended to provide a rich and extensible tool set for model development efforts at USARIEM and to contribute key modeling methodologies directly to other projects.

The environmental Heat Stress Monitor (HSM), a pocket-sized electronic device, combines the USARIEM heat strain prediction model with a miniaturized sensor suite to measure air temperature, humidity, wind speed, solar radiation, and barometric pressure. This device provides tailored local guidance on optimal work/rest cycle limits, safe work time, and hourly drinking water needs for a wide range of military clothing types and work categories.

As part of the warfighter physiological status monitoring (WPSM) program, USARIEM is investigating methodologies needed to integrate real-time local environmental data and warfighter physiological data with predictive model processes. The effective fusion of these two real-time data streams will enable near term environmental strain and performance status predictions for individual warfighters. Research efforts in this area are intended to address capabilities identified in the Operational Requirements Document (ORD) for the Army's Land Warrior program.

The availability of ground level environmental data at high temporal and spatial resolution continues to pose a significant challenge for predictive model development and validation. A Phase II Small Business Innovative Research (SBIR) project to design and build a very small wireless network-capable, expendable, micro-environmental sensing system is underway, and the feasibility of on-body environmental sensors is also being investigated.